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ABSTRACT

An extensive historical backgrou[illegible] an exhibition dealing with the technological augmentation of hu[illegible]ellect is presented. The main theme underlying [illegible]he discussio[illegible]e changing concept of cognition in the last 200 years. Five main [illegible]ews of the learning process are traced as they developed in philosophy and in practical application: the technology of facts (1776-1876), the technology of processes (1876-1925), the technology of communication (1926-1959), the technology of machines (1951-1970), and the technology of man (1971-?). It is suggested that present-day technology can be used to achieve more than the acquisition of facts; by drawing on historical and new results, it may be possible to learn to use technology to enrich the manifold aspects of cognition. A large scale exhibition is described which would trace the evolving aspect of educational technology by showing the various devices which have been used in the process of education. The devices range from hornbook to the computer. Some possible modifications to the exhibition are suggested for locations where there is not sufficient original source material. These include the use of holograms, audiovisual devices, and computer simulations. A list of references is presented together with a guide which annotates the references as a group. (JY)

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# OF LEVERS AND ELECTRONS AND LEARNING AND ENLIGHTENMENT

Technological Augmentation of Cognition
in the United States Since 1776

by UTA C. MERZBACH

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# OF LEVERS AND ELECTRONS AND LEARNING AND ENLIGHTENMENT

Technological Augmentation of Cognition in the United States Since 1776
by Uta C. Merzbach, Ph.D.

## FOREWORD

The Interdisciplinary Communications Program of the Smithsonian Institution conducted a series of interdisciplinary interaction discussions to explore new teaching and training concepts and methodologies, particularly as new technologies provide potentially powerful symbiotic means of augmenting human cognition.

Throughout the dialogues there was a recurrent theme—the need for better communication about the real, non-trivial, potentially useful technologies for aid to learning and to augmenting cognitive powers. One action idea proposed and followed through was the design and development of a museum centered exhibition.

The group was fortunate to be able to enlist Dr. Uta C. Merzbach, Curator, National Museum of History and Technology, to produce this exhibition design. Dr. Merzbach was encouraged and stimulated in her work by discussions at the conferences, and was aided by an *ad hoc* committee which included Robert B. Davis of Syracuse University and Dennis W. Binning, an education/communication consultant who also served as technical officer on the TAC project. Mr. Binning's experience in publishing and editing was also most useful in the actual production of this publication.

Dr. Merzbach's presentation of the historical development of technological augmentation of cognition in the United States since 1776 should serve an audience wider than the creators and technicians who produce exhibitions.

The programs were sponsored by the Personnel and Training Research Programs, Psychological Sciences Division, Office of Naval Research.

M. C. Shelesnyak, Ph.D.
Director, Interdisciplinary
Communications Program

## PREFACE

This work grew out of a request to consider an exhibition at the Smithsonian Institution dealing with the technological augmentation of cognition (TAC). The suggestion for such an exhibition came from a working group on TAC that had been meeting under the joint auspices of the Smithsonian Institution's Interdisciplinary Communications Program and the Office of Naval Research.

Most current discussions about the technological augmentation of cognition revolve about programmed learning and the use of computers. It appeared desirable to treat the problem from a broader historical perspective. Since the National Museum of History and Technology is currently concentrating its efforts on projects pertaining to the celebration of the Bicentennial of the American Revolution, it seemed appropriate to consider an exhibition that would cover the two-hundred-year history of our subject in the United States.

Part II of this study describes a general plan for such an exhibition. It is hoped that this plan may serve as a useful starting point for groups or institutions that are interested in producing an exhibition dealing with all or part of the topics covered here. Among such groups are museums, schools, colleges, historical societies, and community centers, as well as professional or industrial organizations. Whereas few institutions are in a position to develop an exhibition containing original objects covering the entire two-hundred-year period, many are well qualified to treat particular subjects. Thus, numerous historical societies have objects illustrating the application of technology to education in their particular region. Many schools have programs in computer-assisted instruction; a terminal in the school lobby or in a civic center could provide parents and other members of the community with samples of programs used in the schools, and with general historical information about this technique.

Part I is intended to provide preliminary background for the preparation of a historical exhibition. The main theme underlying the discussion has been the change that the dominant concept of cognition has undergone in the last two hundred years. Moving away from the initial view that cognition pertains primarily to the acquisition of factual knowledge, there was a trend toward emphasizing the cognitive process; from

this, with increasing attention being given to the social function of thought, the relationship between cognition and communication became dominant. Finally, with the growing power of technology and the creation of mathematical and mechanical models of cognition, there came a return to the emphasis on factual knowledge. However, it is suggested that present-day technology can be used to achieve more than the acquisition and transmission of facts: By drawing on a variety of new and historical results, one may yet learn to use technology to enrich the manifold aspects of cognition.

Like many specimens of material culture, the objects related to the enhancement of cognition are rarely considered in conceptually oriented discussions of the subject to which they pertain. A historical exhibition can remedy this situation. To promote the bridging of the gap between object and concept, certain familiar objects that lend themselves particularly well to visitor operation or demonstration have been chosen, along with selected topics to which they relate. These topics, taken primarily from the areas of education and psychology, should be well known to students in these fields. It is hoped that such obvious juxtaposition will suggest to the reader opportunities for integrated studies utilizing objects as primary source materials.

To encourage such study in the general area of TAC, Part III includes a brief guide to references that provide useful introductions or bibliographies to different aspects of the subject.

This entire exercise is the joint work of Mr. Victor B. Kley and myself. I am responsible for Parts I and III, and for the general outline of the exhibition described in Part II. Mr. Kley is responsible for the design of the exhibition in Part II, for the concept of the small audio-visual exhibit, and for the idea of introducing the holograph. Except for minor modifications and a few additions, the text accompanying Part II is based on a draft prepared by Mr. Kley. In addition, Mr. Kley prepared all of the drawings included in this study, and aided with the research for Chapters 3 and 4 of Part I. The remarks made in Chapter 5 reflect opinions that we share.

U. C. M.

Washington, D.C.
June 1971


## ACKNOWLEDGMENTS

We wish to thank the following people who assisted in this project:

Drs. S. L. Pressey, J. Popplestone, and M. W. McPherson for graciously providing materials and information;

The staff of the Division of Pre-industrial History at the National Museum of History and Technology for joint help in preparing photographs and identifying objects from the National Collections;

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Miss Sheila K. Ford, of the Section of Mathematics, the National Museum of History and Technology, for rendering a variety of services essential in the completion of the manuscript;

Miss Verley D. George, for sacrificing her "leisure hours" to type and prepare the manuscript;

The staff of the Interdisciplinary Communications Program, Smithsonian Institution, for administrative and editorial assistance throughout the course of this project.

Finally, this is a proper place to acknowledge the long-standing efforts of Dr. Keith E. Melder, former Curator of the Division of Political History, the National Museum of History and Technology, to encourage research and exhibition in this and related areas. It is hoped that this and other preliminary studies may serve as a small contribution to his work.


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# PART I – PRELIMINARY SURVEY

## I. 1776-1876: THE TECHNOLOGY OF FACTS

The intellectual and political upheavals of the seventeenth and eighteenth centuries left hitherto prevailing concepts of cognition a shambles. This was not a novel situation. The problem of cognition, which can be traced to antiquity, traditionally had been linked to major politico-social as well as intellectual systems and hence was subject to overthrow along with these.

When the pre-Socratic Greek philosophers of the fifth century B.C. attempted to resolve the conflict between the conclusions of their rational systems and the observations of everyday life, they attributed the problem to the deception wrought by the senses. Although generally considering external knowledge as entering the individual by way of the senses, these philosophers conceived of "thinking" as something distinct from "perception." Presumably a thinker was distinguished by the fact that in him a certain amount of internal knowledge combined with the received external knowledge to overcome the effect of the transmitting senses. Since the opinions of common mankind depend on the perception of the senses, it followed that truth could become known only to those uncommon few who devote themselves to the pursuit of thinking. This divisive notion, presumably attractive to one who considered himself a thinker, had obvious implications for the art of government: In the more balanced Socratic-Platonic framework, with the concept that virtue is knowledge, (rational) knowledge is recollection, and sense-perception is the prompter providing the occasion for recollecting, it resulted in the hierarchy of the *Republic,* in which the decision-making power of government is entrusted to the class of those who have passed through the system of higher education training them in rational knowledge (mathematics and logic). Once Aristotle's systematic methodology of rational knowledge was available in the form of his formal logic, this for centuries remained the bulwark of the curriculum for training the future secular and clerical leaders of the western world.

Along with the Aristotelian methodology and the Platonic theory of cognition, the seventeenth century was heir to anti-Aristotelian strains: There was the probabilistic attitude toward the certainty of knowledge derived from the ancient Sceptics; the elevation of the role of sense perception inherited from both Sceptics and Stoics; the related Stoic notion, soon to become associated with the name of John Locke, of the mind as a blank tablet on which the external world leaves its marks; the emphasis on inner experience and introspection taught by Augustine; and the common-sense logic of Peter Ramus.

Whereas the Puritans of seventeenth century New England had developed a rationalism that responded to these earlier traditions, the founders of the Republic remained closer to the thought of their own time. Men of the eighteenth century could draw upon a broad cross-section of European systems contributing to the confusion of epistemological dogma: From Descartes' basic framework had sprung the rationalistic system of Spinoza, the theological escape of Malebranche, and the empirical foundation of Locke, which in turn was subjected to purification by Berkeley and ultimate reduction by Hume. From Leibniz's suggestions concerning the monad and the nature of pre-established harmony followed the rigid theory of Wolff. From Newton's natural philosophy arose the main versions of English and French deism. Among Americans, we can single out readers and followers of major French, Swiss, German, Scottish as well as English philosophers.

However, it was John Locke whose approach to the problem of cognition was most widely cited in late eighteenth century America, while independent views on the subject were being shaped that reflected the attitudes and contradictions of the times. Locke had maintained the Cartesian principle of the certainty of self-consciousness. He had emphasized the need for the senses in admitting ideas to the mind. He had distinguished among intuitive knowledge, which brings the certainty of Descartes' self-knowledge; demonstrative knowledge, which deals with the relation of ideas through "intervening ideas" or proofs; and "sensitive" knowledge, or knowledge of specific external objects. Some readers of Locke in America modified his concept of demonstrative knowledge or differed with him on the degree of certainty of the knowledge imparted by the senses. But there was a characteristic adherence to the notion of self-evident truths. It seemed not to matter whether these were based on "intuitive certainty" or on "conviction" akin to that accompanying the association of ideas whereby Hume had only recently replaced the traditional concept of the cause and effect relation. Indeed, many an American seemed independently to agree to the rejection of all that does not contain "abstract reasoning concerning quantity or number" or "experimental reasoning concerning matter of fact and experience (Hume 1749, pt. III, sec. 12)."

In their public utterances, Americans of the post-revolutionary period appear to have referred less to the epistemological thought of their living contemporaries across the water than to that of their precursors. However, they were well acquainted–with regard to person as well as to conceptual orientation–with many of the French materialists, the Scottish common sense philosophers, the school of Condillac, and the Swiss educational reformers. At a time when the young French republic in cleansing the curriculum of the *École Normale* substituted "The Analysis of Human Understanding" for "Philosophy," America's leading thinkers were simply *en kairo* in attempting to develop their own strain of "fact-determined" epistemology.

When translated into the realm of general education,

the emphasis on "facts" and "truths" served to support a subject-matter oriented approach. This partly explains the heavy reliance in the primary schools on the basic disciplines of reading, writing, spelling, grammar, arithmetic, and geography. On a broader level, this orientation supported a general emphasis on the acquisition of "knowledge," that is, of "facts." In addition, as a member of the community, the individual was encouraged to transmit and share this knowledge with his fellow-citizens. Hence, "augmenting cognition" for a long time meant simply "increasing the stock of factual knowledge."

**READING**

In looking for ways in which technology was used to implement the oft-stated interest in the increase and diffusion of knowledge, it is instructive first to survey developments in the technology of reading.

In 1776 each of the thirteen colonies had at least one printing press in operation; by 1876 the same could be said of each of the areas comprising the future first forty-eight states. Americans were commended at the time of the revolution for their reading habits: Boston already had about 50 libraries; the sale of almanacs, broadsides, newspapers and books was wide-spread. By the turn of the century the country is estimated to have had nearly a hundred periodicals and about 150 active newspapers; these figures increased rapidly, and the increase was linked to numerous technological breakthroughs in printing. Estimated national publications sales figures for books rose from $2,500,000 in 1820 to the five-fold sum in 1850 (Goodrich 1856; Lehmann-Haupt 1951).

Despite these promising statistics, reading in most schools was severely limited for much of this period. In the primary school, the hornbook was slowly disappearing about the time of the Revolution. In its place remained the primer and the speller, to which sets of cards or charts were added. Several decades passed before the advent even of the graded reader. This state of affairs was symptomatic partly of the strength of existing tradition but more of the generally deprived condition in which the schools–particularly the district schools–had been left by the Revolution.

The hornbook had consisted of a printed sheet glued loosely to a more or less paddle-shaped piece of wood. It was covered with horn, which in turn was held down by thin metal strips. Some hornbooks were covered with leather, which usually had an ornamentation impressed on both the back and the handle. (Figs. 1 and 2) There

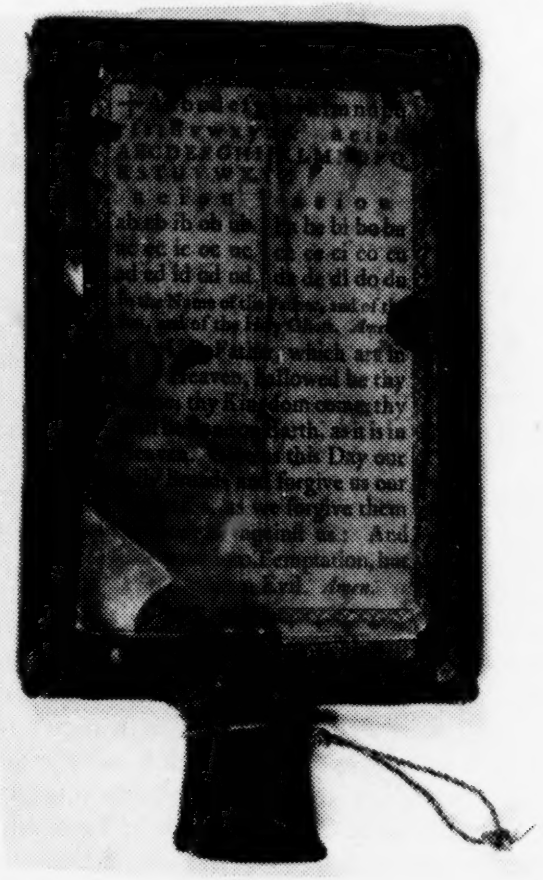


**Figure 1.** Hornbook, front. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

**Figure 2.** Hornbook, back. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

also existed paper-covered hornbooks with or without ink-impressions. The content of the hornbook followed a fairly standard format: It usually contained the alphabet, syllabarium, Invocation and the Lord's Prayer. Most hornbooks were imported from England. They were replaced by the more easily made battledores, consisting simply of the wooden tablet with handle on which the printed sheet was glued. There were also cardboard battledores. Presumably children used the sturdier varieties to play a game of battledore and shuttlecock when not memorizing their syllables (Tuer 1896; 1968).

Primers had been common in colonial days. Originally a prayer-book, the primer had retained its religious characteristics when it changed into a children's reading text. The *New England Primer* dated back to the late seventeenth century; in various versions it persisted well into the first half of the nineteenth century. It contained the alphabet, the customary combinations of syllables, and a variety of anecdotes and verses of a generally religious or moral nature, though not necessarily designed to spread feelings of tolerance or security among children (Figs. 3 and 4).

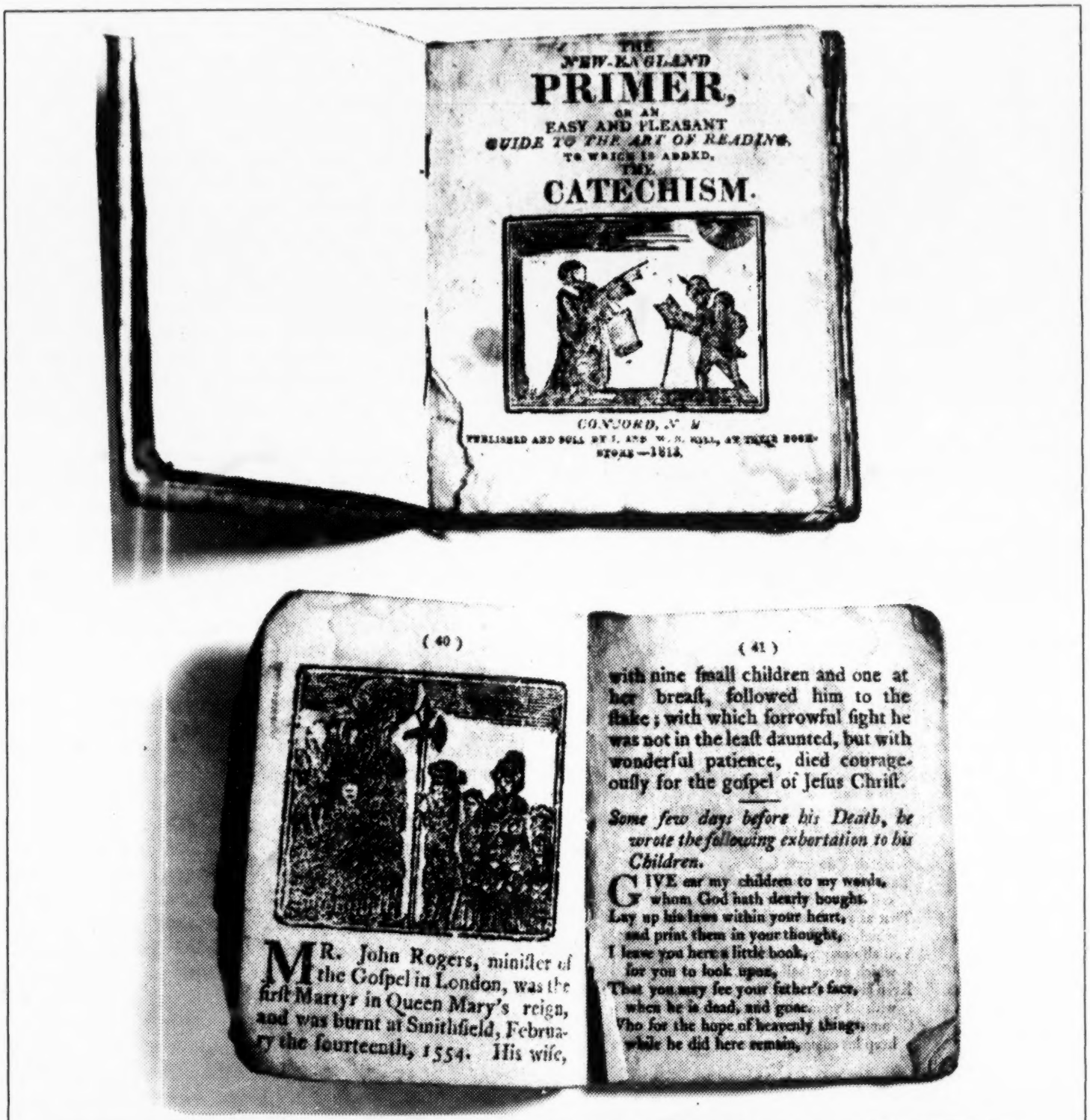

THE
NEW-ENGLAND
PRIMER,
OR AN
EASY AND PLEASANT
GUIDE TO THE ART OF READING.
TO WHICH IS ADDED,
THE
CATECHISM.
CONCORD, N. H.
PUBLISHED AND SOLD BY J. AND W. S. HILL, AT THEIR BOOK-STORE.—1813.
( 40 )
MR. John Rogers, minister of the Gospel in London, was the first Martyr in Queen Mary's reign, and was burnt at Smithfield, February the fourteenth, 1554. His wife,
( 41 )
with nine small children and one at her breast, followed him to the stake; with which sorrowful sight he was not in the least daunted, but with wonderful patience, died courageously for the gospel of Jesus Christ.
Some few days before his Death, he wrote the following exhortation to his Children.
GIVE ear my children to my words,
Of whom God hath dearly bought.
Lay up his laws within your heart,
And print them in your thought,
I leave you here a little book,
For you to look upon,
That you may see your father's face,
When he is dead, and gone.
Who for the hope of heavenly things,
While he did here remain,

**Figure 3.** *The New England Primer* (above), Concord, N.H., 1813. *The New England Primer, improved* (below), Wilmington, 1808. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

THE

AMERICAN

JUVENILE PRIMER.

AND

FIRST STEP TO LEARNING,

CAREFULLY ARRANGED ON A NEW, SIMPLE, AND INTERESTING PRINCIPLE.

Philadelphia:
TURNER & FISHER, 11 N. SIXTH STREET.
New York:
TURNER & FISHER, 52 CHATHAM ST.
1838.

**Figure 4.** *The American Juvenile Primer,* Philadelphia 1838. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

Basic to the content of the New England primer was the Catechism of the mid-seventeenth century Westminster Assembly (Johnson 1904; 1963); other catechisms were drawn upon as well. The verses and stories of the primer were usually illustrated with woodcuts. In conjunction with, or independently of, the primers, Bibles and prayer books continued to serve as basic reading both in the schools and in the home. Occasionally these were adapted to teaching reading, by excerpting and illustrating desired passages (Fig. 5).

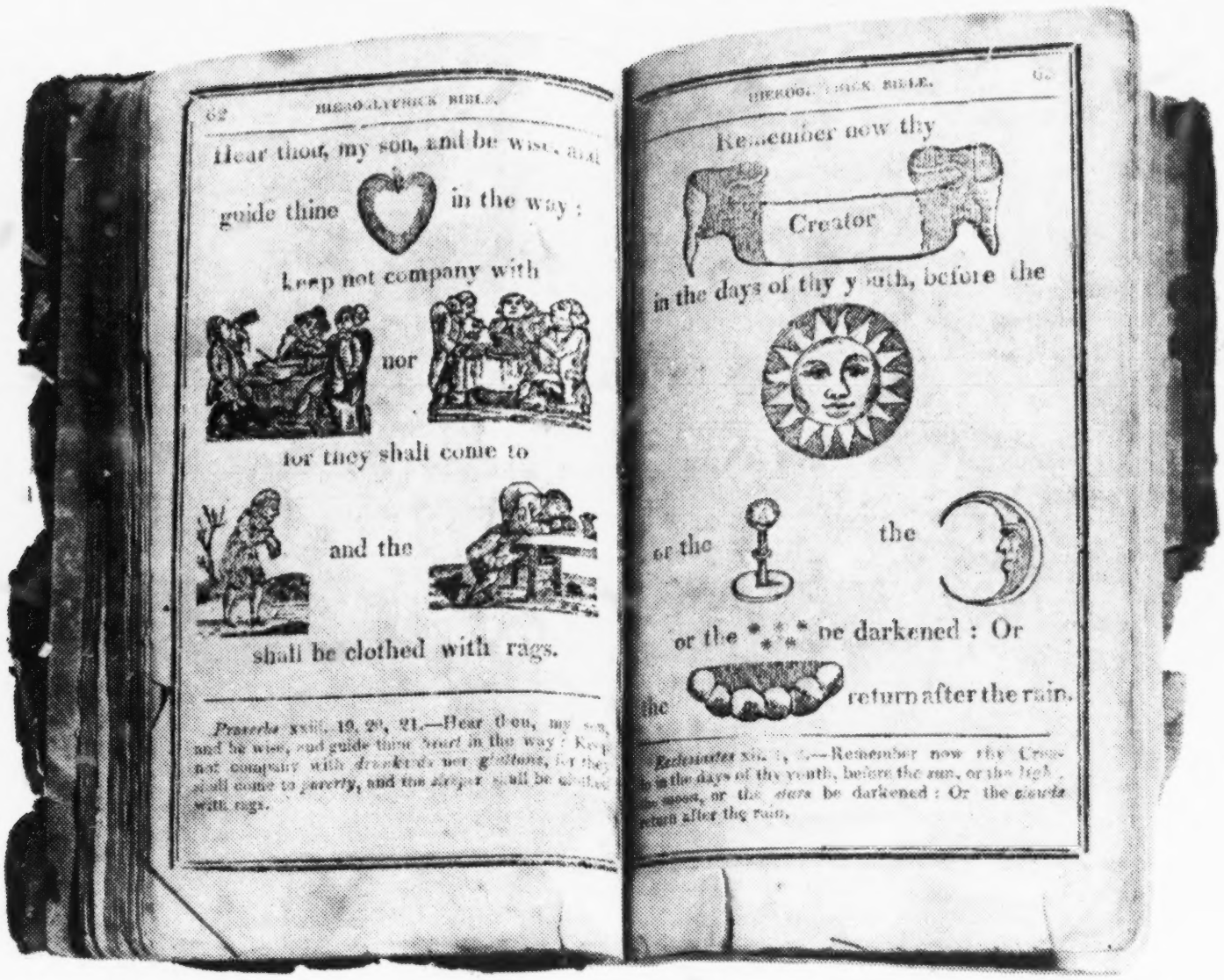
Spelling books, too, were carried over from colonial days; but the most famous of them was a product of the new nation. After the publication in 1783 of Noah Webster's first speller, his spelling books, revised regularly, undergoing various changes of title, and published by a number of different publishers, dominated the market for decades. The "Old Blue-Back," so called because of the binding that consisted of blue paper pasted over oak boards attached to a leather back, served as all-purpose primary textbook for the first two or three years in many schools. It was in fact more than a spelling book. Usually beginning with a section on the articulation of sounds, there followed a page on the alphabet, a syllabarium and related lists of letter combinations, and finally spelling columns interspersed with generally illustrated short stories. It is characteristic that even in relatively late editions the famous picture of Noah Webster that usually appeared on the inside front cover was crowned with the phrase "Who taught millions to read but not one to sin (Webster 1850)." Other spelling books of the period differed only in minor ways.

The use of wall charts and cards in schools was supported by the followers of the Lancasterian system of instruction. Although this system encouraged the same rote memorization and responses as traditionally prevailing methods, it contributed to the spread of educational accessories, by promoting devices designed to aid schools and pupils that could not afford the use of individual primers, spellers, and other standard aids and furnishings.

The book that outdid Webster's Speller in popularity was William McGuffey's Reader. The McGuffey Readers represent the first major American effort at a graded textbook series. The first Reader was published in 1830. Within a little over a decade, William McGuffey and his brother had produced their first graded series. From then on, publication of these Readers spread with phenomenal rapidity, a development aided by the simultaneous growth in population, the beginnings of the public school system, and the use of stereotypes; the Readers were produced on stereotypes from the 1840's until the 1860's, when they were reproduced by the electroplating process.

During the hundred years in question, printing and publishing techniques changed drastically. During a period in which the United States still depended on imports in many manufacturing fields, the country not only kept up with but helped lead the advance in the technology of printing and publishing. The resulting rise of this industry is shown by the fact that whereas in the 1820's less than one-third of the American's reading material was produced in this country, by 1880 the figure had risen to nearly 80%.

One of the major technological developments pertinent to this growth was the change in the printing press. Whereas colonial presses had been wooden, involving the application of a vertical impressing force (Fig. 6), the presses of the mid-nineteenth century were made of iron, and most utilized cylinders rather than planes, both for impressing and for inking. The conversion to iron allowed the application of far greater pressures than had the wooden press, and was essential for the conversion to steam-driven presses. Cylindrical presses altered radically the printing of newspapers and similar materials. The first American iron press to attract considerable attention was the Columbian press, invented by George Clymer in Philadelphia (Fig. 7). Offered in America from 1813 on, the inventor patented it in 1817 in England where it soon outsold the earlier iron press invented by Lord Stanhope in 1799-1800. A set of levers and counterweights replaced the traditional screw used to convey power to the impressing platen. After some rather short-lived ventures in running presses literally with horse power, steam-driven presses began to come


62 HIEROGLYPHICK BIBLE.

Hear thou, my son, and be wise, and
guide thine [heart] in the way:
Keep not company with
[drunkards] nor [gluttons]
for they shall come to
[poverty] and the [sleeper] shall be clothed
with rags.

*Proverbs* xxiii. 19, 20, 21.—Hear thou, my son, and be wise, and guide thine *heart* in the way: Keep not company with *drunkards* nor *gluttons*, for they shall come to *poverty*, and the *sleeper* shall be clothed with rags.

HIEROGLYPHICK BIBLE. 63

Remember now thy
[Creator]
in the days of thy youth, before the
[sun] or the [moon] and the
[stars] be darkened: Or
the [clouds] return after the rain.

*Ecclesiastes* xii. 1, 2.—Remember now thy Creator in the days of thy youth, before the *sun*, or the *light*, or the *moon*, or the *stars* be darkened: Or the *clouds* return after the rain.

**Figure 5.** *Hieroglyphick Bible,* Plymouth/Charlestown, 1820. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

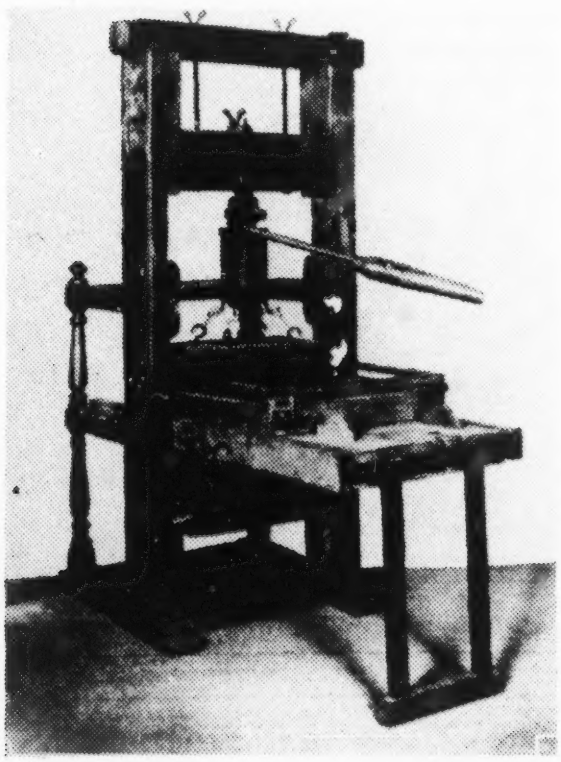


**Figure 6.** Wooden Press, 17th century, used by Stephen Day (?). *Vermont Historical Society. Photograph courtesy of the Smithsonian Institution*

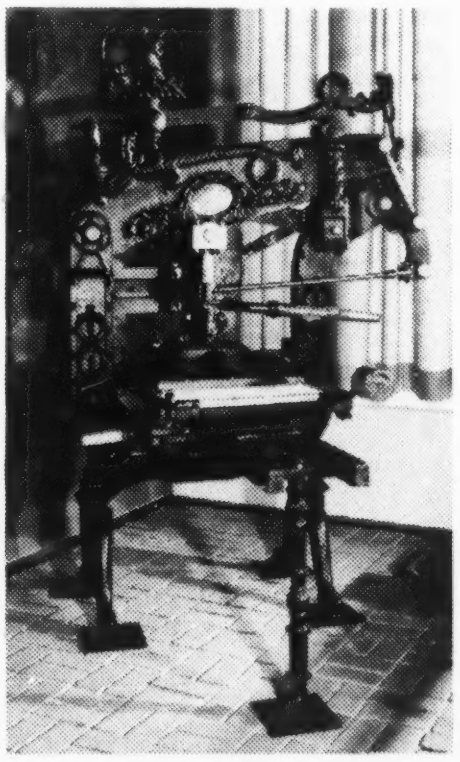


**Figure 7.** Columbian Press, Scotland, circa 1865. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution*

into use in the 1820's. Perhaps the most widely used bed-and-plate press of this type was that invented and perfected by Isaac Adams in the 1830's.

Cylindrical presses, first put into use in England about 1810 and gradually developed in England and France, were improved further by Robert Hoe of New York. In 1846-47 he made a more notable contribution by building a rotary press which was to see service for the *Philadelphia Public Ledger.* Though the machine produced 20,000 impressions an hour it required more than two dozen attendants to feed and remove the sheets (Fig. 8). In 1865 the problem was overcome with another Philadelphia invention, the rotary of William Bullock designed to be fed from a continuous paper roll.

Besides the improvements in newspaper and book presses, significant changes occurred in the design of jobbing presses used for printing miscellaneous materials such as broadsides, advertisements, invitations, certificates, announcements, and such (Fig. 9). In 1839

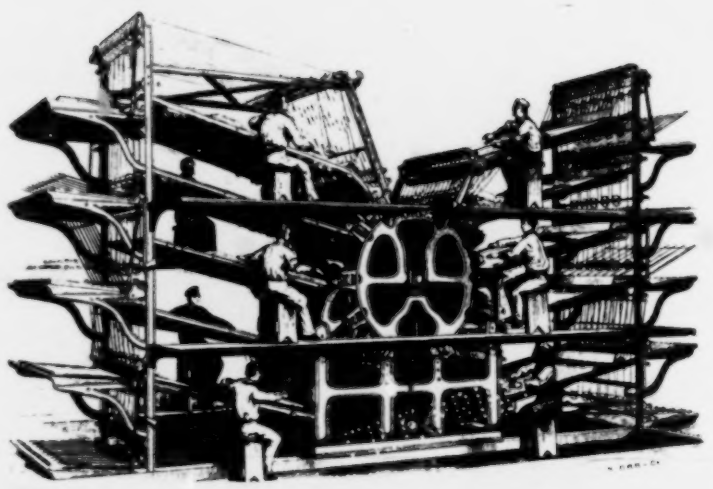
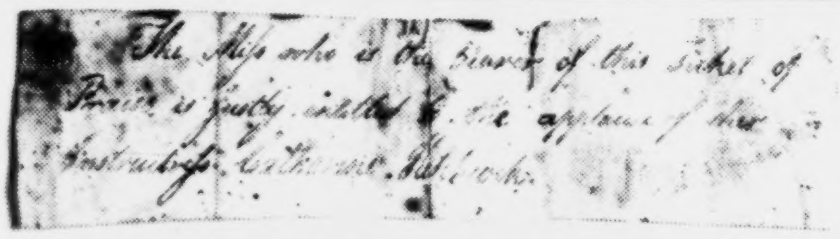


**Figure 8.** Hoe Ten Cylinder Printing Press. *Catalog,* R. Hoe & Co., 1867. *Photograph courtesy of the Smithsonian Institution.*



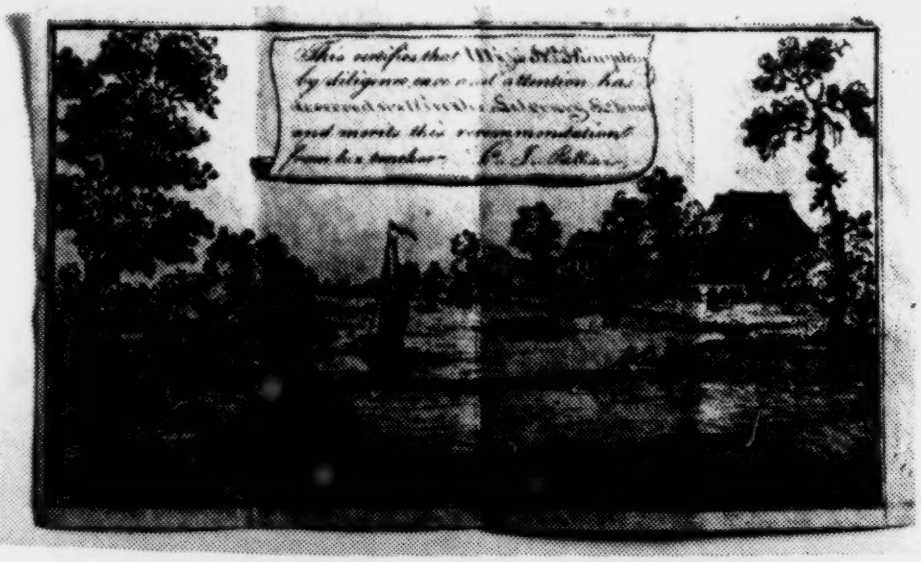


**Figure 9.** Medals and Certificates of Merit. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

Stephen Ruggles of Boston completed a self-inking treadle press which, after little more than a decade, he superseded with a less complex press having a vertical bed, a feature that was to remain a characteristic of jobbing presses.

While presses were improved steadily, type setting remained a manual operation until in 1838 David Bruce of New York patented a successful mechanical type-casting machine. The mold was brought in contact with a melting-pot by a rocking frame which it opened and closed in synchronization with the rocking. A few years thereafter, in 1841, another major event took place in New York City when electro-typed plates were introduced, making possible, among other things, the reproduction of wood-engravings. In the electrotype process a wax impression is made, a copper or nickel shell deposited by electrolysis, and the melted type mold cast into the back of the shell. The process soon overtook the stereotype process that had been introduced to New York about 30 years before. In stereotyping, metal plates were cast from a mold made of plaster at one time, of paper-mache subsequently. Stereotyping was first used to produce books that required frequent reprinting such as Bibles, books of prayer, primers and other textbooks. By about 1860 the technique of casting curved stereotype plates for use with the cylindrical newspaper presses was perfected.

Progress was slower in the development of type-composing machines. After the invention in 1822 of such a machine, several decades passed before they became generally usable. Rather complex type-setting machines were in operation by about 1860. However, after another two decades, they were all superseded by the linotype machine.

Major improvements were to be found in the art of book illustrations as well as in the binding of books during the century. In the colonial period illustrations were restricted to woodcuts and copper-plate engravings, with some relief cuts. About the 1820's steel engravings, previously introduced in the production of bank notes, came to be especially popular in children's books. About the same time, the use of lithography began to spread slowly, with early American specimens of color lithography dating from the 1830's.

By the mid-1850's photographic illustrations were beginning to be used, the first notable example in this context being John Draper's *Human Physiology* of 1856. Major developments in the binding of books included the replacement in the 1820's of the "boarding" by the "casting" process. The sheets were sewn separately from the case, which was then joined to it by pasting them to a hinge and pasting down the end papers. One of the first textbooks with flexible pasteboard sides was Parley's *Geography* of 1829 (Anderson 1962). At the same time the usually paper-covered boards occasionally began to be replaced by cloth-coverings: Until the 1880's, the cloth was mostly imported from England. Meanwhile, bookbinding processes gradually changed from manual to machine operation. By 1840, rolling and embossing presses were made in the U.S., and they were followed in 1845 by a steam-powered stamping press and a hand-operated backing machine. After yet another decade, folding machines came into use together with thread-sewing machines which became more widespread in the late 1870's.

## WRITING

Closely related to, and often overlapping with, the impact of technology on training in reading is the effect technology had on writing. In home, business, and school the traditional quill-pen formed the chief writing implement through the first part of the nineteenth century. Pencils were expensive, rare, and until 1861, manufactured abroad. Ink for a long period continued to be home-made, either from a powder base, or from the juice of various trees and bushes. The most far-reaching changed occurred in the production of paper. Other developments, of particular importance for training in the schools, were the introduction of the blackboard and the slate.

The paper available after the Revolution was either expensive or of poor quality or both. The paper used in schools tended to be particularly coarse. With the growth of the printing industry, the problem was compounded, since the increased demand led to a shortage of linen and cotton rag in Europe. However, during the first part of the nineteenth century the number of paper mills in the United States increased substantially–from about 100 in 1800 to approximately 500 in 1850. With this basis, and the potential softwood resources of the South, it is apparent that paper manufacture was to become a major industry once a process was found to appropriately process wood pulp. Initial efforts to utilize wood pulp were generally unsuccessful because the mechanical devices used tended to ruin the fiber. However, this situation changed after 1850. With the issuance in 1854 of a U.S. patent for the "soda" process of making the pulp by boiling wood in caustic alkali, mechanical processing means could be discarded. In the 1860's, the "soda" process found its competition in the chemical sulphite process of wood reduction (Lehmann-Haupt 1951, p. 88).

In the meantime, the blackboard had made its appearance in American schools and colleges about 1810. The earliest known references tie it to the teaching of arithmetic in the primary school and mathematics in the colleges. Its use spread in the 1820's, and by the 1830's it was considered a basic piece of school equipment. In the 1840's, guides for teachers on the use of the blackboard began to appear. These frequently included discussions of the making and care of the board, as well as suggestions for the types of problems and exercises to be placed on it. They also reflected the changing use of the board from the early relatively small display device

used by the teacher, (Fig. 10) to the larger unit that occasionally covered all three walls in the schoolroom and could be used by a class of students. The early blackboards were simply painted or stained pieces of wood. Because of this, it was common for teachers in district schools in the first half of the nineteenth century to construct their own boards, or simply to smooth down a wall of their schoolroom and to paint it black.

Slates, too, though known in the colonial period, only began to be widely used in the nineteenth century (Fig. 11). Their use spread steadily, so that by 1850 they had become a standard accessory for the average young scholar, only gradually replaced when pencils and paper became cheap enough to be used by pupils.

Aside from these widely known pieces of equipment, more highly specialized aids to writing appeared in various places. Thus, one finds an 1864 patent (U.S. Patent No. 44, 778) for a "Diagram for Teaching Penmanship." The diagram shows the desired position of the pupil's arm and hand; the inventor claims that the pupil will learn to assume this position in writing by placing the diagram on the desk and adjusting his arm and hand accordingly. Another patent, granted in 1875 (U.S. Patent No. 161, 192), was for a copy-slip for teaching penmanship. The use of copy-slips was not new by any means; slips of paper with letters to be copied by the pupil had been published before 1800, and had been in use ever since. However, the patent in question was for a transparent copy-slip; this had the advantage that, after copying it, the pupil could place the slip on top of his work and see how well he had done. In other words, this copy-slip provided the "knowledge of result" feature that was to play such an important part in modern teaching machines.

## ARITHMETIC

It was in the teaching of arithmetic that the impact of changing concepts of cognition and learning became particularly apparent through the use of simple technological products. Throughout most of the colonial period and the early years of the Nation, arithmetic had been taught as a subject to be mastered by the memorization of numerous rules. Whether taught with the help of a hand-written ciphering book or one of the standard arithmetics, such as the tremendously widely used work by Nicholas Pike (1788), the technique of rules and problems, memorization, solution, and recitation varied little. In the 1820's this approach began to change.

The changed approach to teaching arithmetic may be associated with the spread of the educational ideas disseminated through the publication of Warren Colburn's *First Lessons in Arithmetic on the Plan of Pestalozzi* in 1821. However, the ideas of Pestalozzi had aroused interest in restricted circles a generation before this. One finds a translation and adaptation of Pestalozzi's *Leonard and Gertrude* published in Philadelphia in 1801. Shortly thereafter William MaClure, the native Scottish businessman, geologist, and natural historian, then but recently settled in Philadelphia, visited Pestalozzi's school

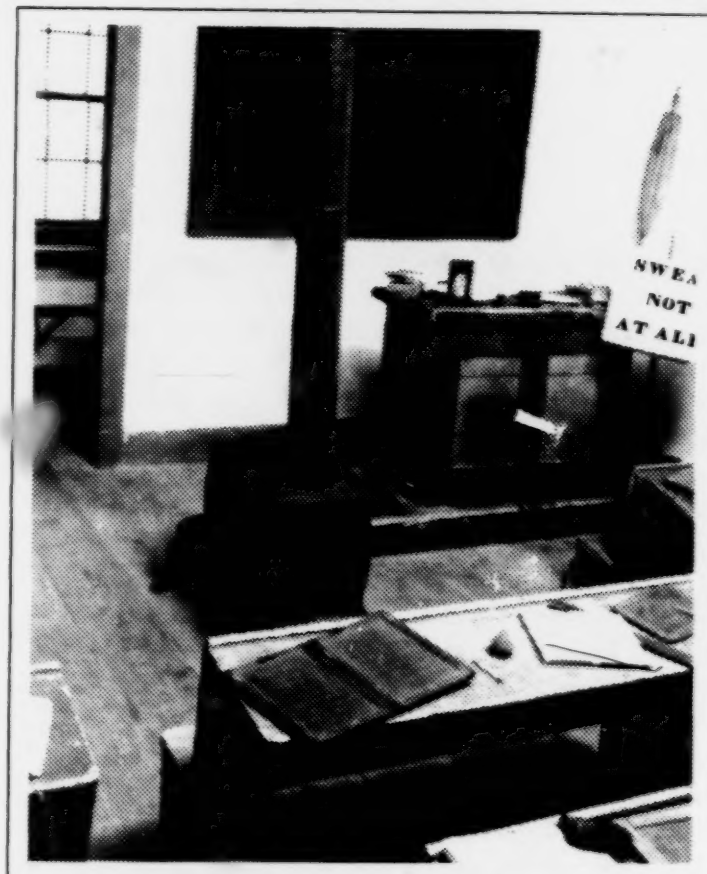


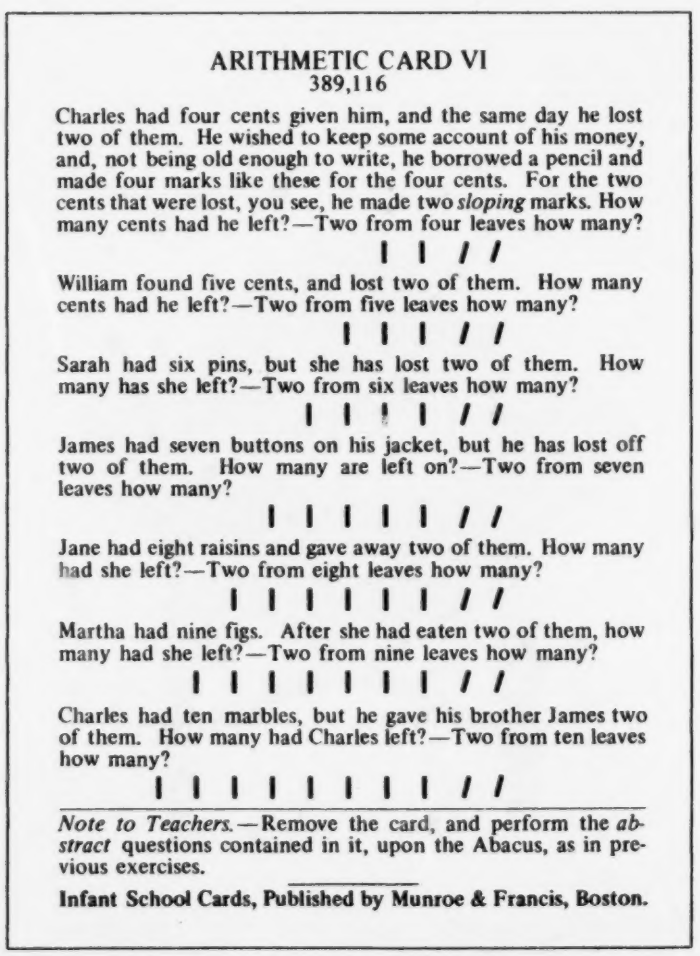

**Figure 10.** Schoolroom Exhibit from Mason's Island, Conn., 19th century. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

**Figure 11.** Slate and Slate Pencil. *National Museum of History and Technology. Photographs courtesy of the Smithsonian Institution.*

in Yverdon, Switzerland, as well as that of Pestalozzi's disciple Fellenberg at Hofwyl. According to tradition, he attempted to persuade Pestalozzi to come to Philadelphia; Pestalozzi recommended his "co-adjutor," Joseph Neef. Neef conducted a successful Pestalozzian school in Philadelphia but did not exert much direct influence through his teaching, presumably because he left Philadelphia after two years to move to the open spaces of Chester, Pennsylvania. From there he later resettled to Kentucky (Monroe 1969), and eventually to New Harmony.

In 1808 in Philadelphia, Neef published a work entitled *Sketch of a plan and method of education founded on an analysis of the human faculties and natural reason, fitted for the offspring of a free people and for all rational beings.* In it he described Pestalozzi's method of object teaching, and listed a hierarchy of the sources of knowledge: First are the senses, from which everything should be derived that can be. The second source is memory, to be used only when the first source is "absolutely inaccessible"; the third is analogy. Human evidence is to be called upon only when none of the preceding are sufficient. Books are last on the list. Like his mentor, Neef emphasized the importance of oral communication for the learner. It was to be practiced in the study of objects found in the learner's environment. These were to be examined according to a sequence of steps involving study of the object as a whole; of various properties and relations of two objects with regard to one another, or of an object with regard to a part of itself; of the quantity, position, qualities, form, organic function and uses of the object; and of the resemblance and differences of the object to other objects. Finally there was to be a precise summary of all that had been done. Although the primary emphasis was on objects occurring in nature, it is easy to understand that three-dimensional representations generally would form an important part of teaching according to this doctrine.

When applied to arithmetic, Pestalozzian teaching encouraged use of the number frame, of illustrated charts, of time pieces and similar objects. The numeral frame or abacus frequently consisted of a square wooden frame subdivided by ten wires, on each of which ten wooden balls were strung. These balls were often grouped in twos and threes by painting them in different colors. There were variations on this basic system, especially in the number of wires. The fundamental simplicity of the device made it possible to use home-made numeral frames as well as standard commercial products. Teachers used the frame as a demonstration device; thus, instead of simply writing "2+2=4" on the blackboard, the teacher performed the operation on the frame while stating the problem. The illustrated charts could be used either independently or in conjunction with the numeral frame. (Figs. 12A, 12B and 13) Arith-



ARITHMETIC CARD VI
389,116

Charles had four cents given him, and the same day he lost two of them. He wished to keep some account of his money, and, not being old enough to write, he borrowed a pencil and made four marks like these for the four cents. For the two cents that were lost, you see, he made two *sloping* marks. How many cents had he left?—Two from four leaves how many?

William found five cents, and lost two of them. How many cents had he left?—Two from five leaves how many?

Sarah had six pins, but she has lost two of them. How many has she left?—Two from six leaves how many?

James had seven buttons on his jacket, but he has lost off two of them. How many are left on?—Two from seven leaves how many?

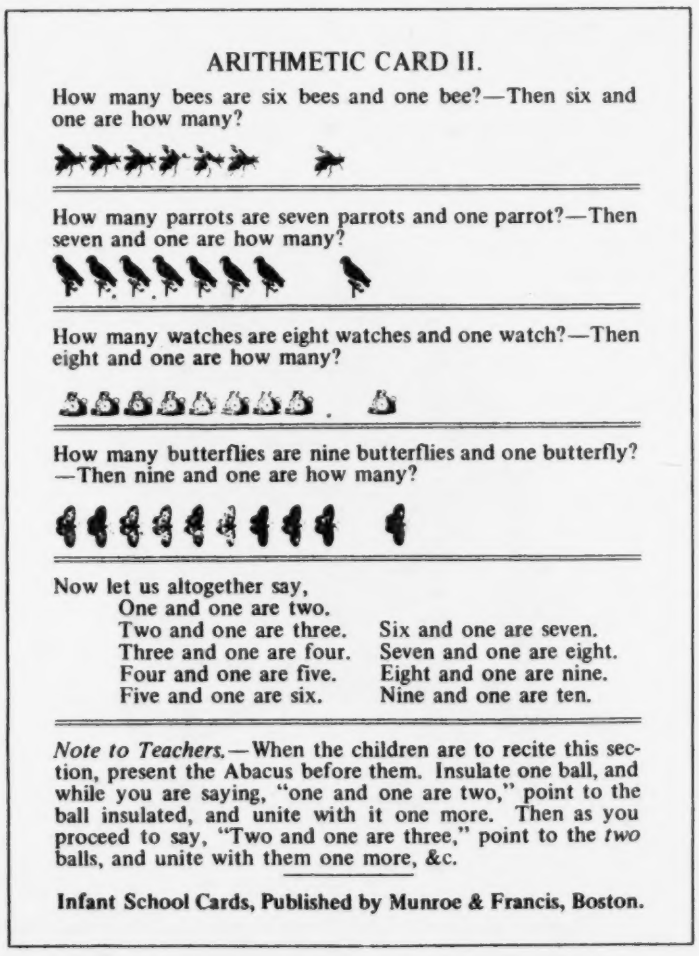
Jane had eight raisins and gave away two of them. How many had she left?—Two from eight leaves how many?

Martha had nine figs. After she had eaten two of them, how many had she left?—Two from nine leaves how many?

Charles had ten marbles, but he gave his brother James two of them. How many had Charles left?—Two from ten leaves how many?

*Note to Teachers.*—Remove the card, and perform the *abstract* questions contained in it, upon the Abacus, as in previous exercises.

**Infant School Cards, Published by Munroe & Francis, Boston.**



ARITHMETIC CARD II.

How many bees are six bees and one bee?—Then six and one are how many?

How many parrots are seven parrots and one parrot?—Then seven and one are how many?

How many watches are eight watches and one watch?—Then eight and one are how many?

How many butterflies are nine butterflies and one butterfly?—Then nine and one are how many?

Now let us altogether say,

| | |
|---|---|
| One and one are two. | |
| Two and one are three. | Six and one are seven. |
| Three and one are four. | Seven and one are eight. |
| Four and one are five. | Eight and one are nine. |
| Five and one are six. | Nine and one are ten. |

*Note to Teachers.*—When the children are to recite this section, present the Abacus before them. Insulate one ball, and while you are saying, "one and one are two," point to the ball insulated, and unite with it one more. Then as you proceed to say, "Two and one are three," point to the *two* balls, and unite with them one more, &c.

**Infant School Cards, Published by Munroe & Francis, Boston.**

**Figures 12a & 12b.** Arithmetic Cards, Munroe & Francis, Boston. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

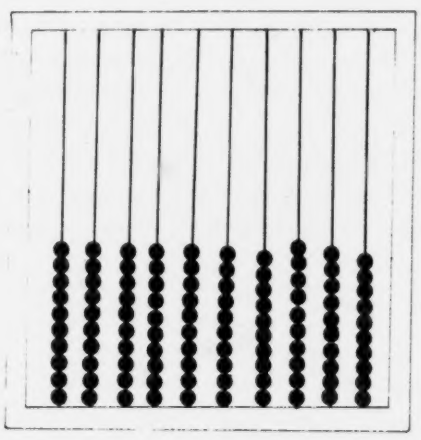



**Figure 13.**

metic operations, particularly addition and subtraction, were demonstrated by letting certain objects represent the numbers in a given problem. The depiction of a number of birds perched on a fence was, of course, a favorite device to illustrate subtraction; the subtrahend was simply represented by birds flying away.

### GEOGRAPHY

Along with reading and writing, grammar, and arithmetic, geography throughout the period under consideration was one of the four basic disciplines taught in the primary schools. During the colonial period, imported globes had been used in the colleges and in a few schools that could afford them. At the beginning of the nineteenth century the domestic manufacture of globes was undertaken by James Wilson of Vermont. His globes were exhibited in Boston in 1814, and soon thereafter Wilson and his sons put the manufacture of his globes on a regular commercial basis (Bedini 1964). By 1830, globes were considered a requisite piece of school equipment, at least in New England; teachers in schools that still could not afford them were encouraged to make substitutes, using oranges, pumpkins and similar representations of the earth (Anderson 1962). While commercial publishers of globes (Figs. 14A and 14B) tended to follow the traditional techniques of manufacturing, individual inventors tried their skill at various innovations (U.S. Patent Office Class 35/40-43): There were relief globes, hanging globes, hemispheric globes, blank globes, flattened globes and the like.

The use of maps, too, varied with the relative affluence of the user. Although standard printed maps were widely recommended, the maps found in the classroom were frequently crudely home-made items. Properly printed maps were made by copper-plate engraving, which did not allow mass production from a single plate. The subsequent growing availability of maps was a function of conceptual innovations, of improvements in printing technology, and of new information obtained from actual surveys. Thus, the first American geological atlas was produced by William MaClure (1809).

After 1850, the innovations suggested by A. Guyot gained international acclaim for American maps, as, for example, at the International Exhibition in Vienna of 1873. The work long assumed to be "the first printed book on American machine-made paper" was Lavoisne's *A Complete Genealogical, Historical, Chronological, and Geographical Atlas* published in 1820 (Lehmann-Haupt 1951, p. 85).

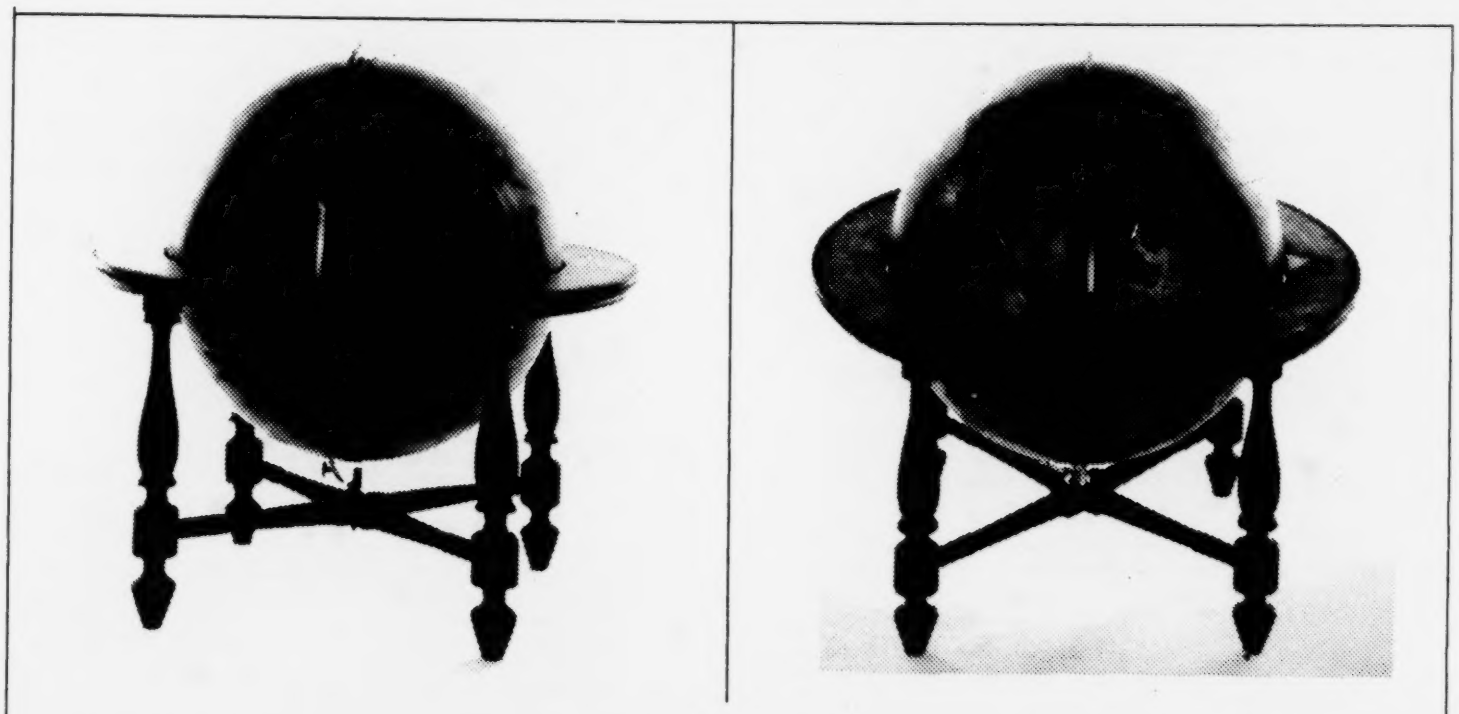


**Figure 14.** Paired Set of Terrestrial and Celestial "Wilson" Globes, Cyrus Lancaster, Albany, New York. *Photograph courtesy of the Smithsonian Institution. National Museum of History and Technology.*

Techniques for producing maps by steel-plate engraving, lithography, zincography, electrotypes and chromolithography all brought improvements in the quality of maps, without, however, appreciably decreasing their cost. The decade of the 1870's at last marked a major technological breakthrough in mapmaking with the introduction by Rand McNally of a new relief line engraving process that resulted in a sharp drop of the cost of maps and atlases. Whereas completed Government-sponsored surveys were restricted to specific time-limited projects or local activities until the 1830's, from then on the United States Coast Survey was involved in steady mapping of the coastal regions; this work was supplemented by regional mapping undertaken by various States, by the military, and by local surveyors. The great government-sponsored surveys about 1870 were climaxed by the formation of the United States Geological Survey in 1879.

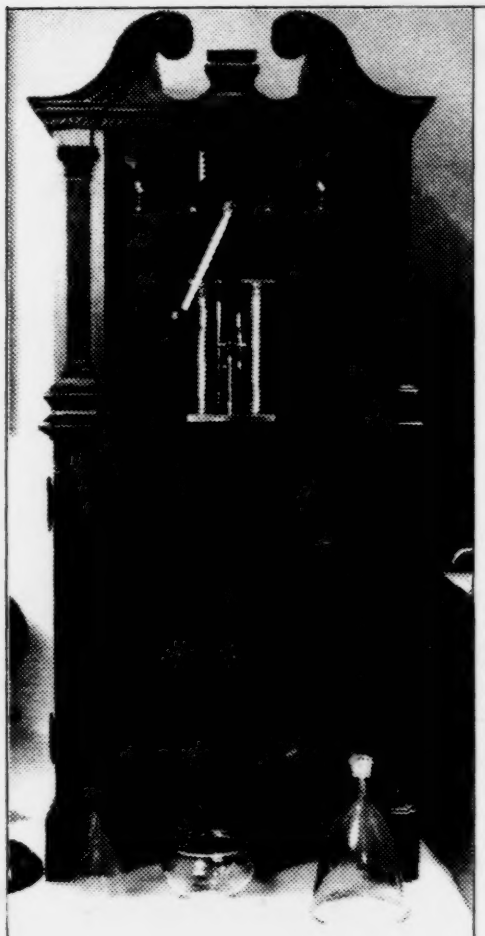


**Figure 15.** Air-Pump, 18th Century, used at Bowdoin College

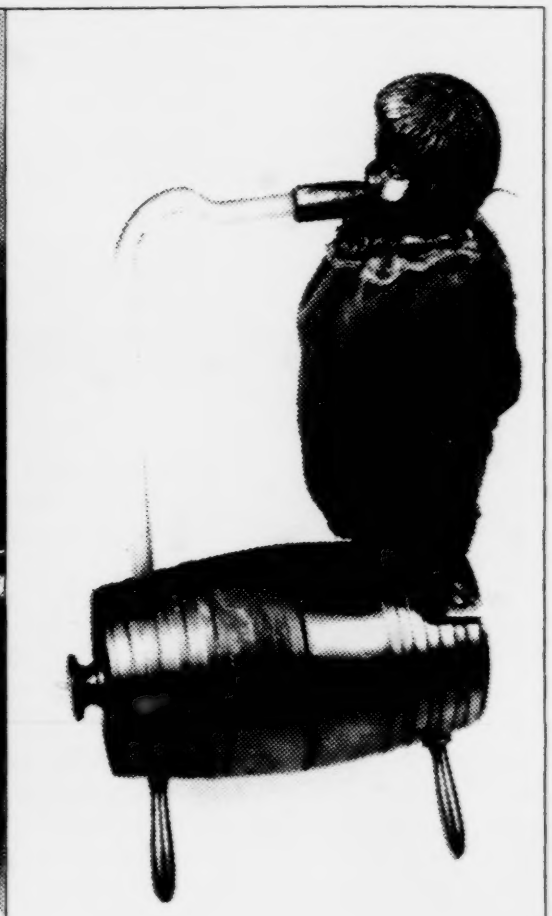


**Figure 16.** Bacchus in Vacuo, circa 1800; used at Middlebury College

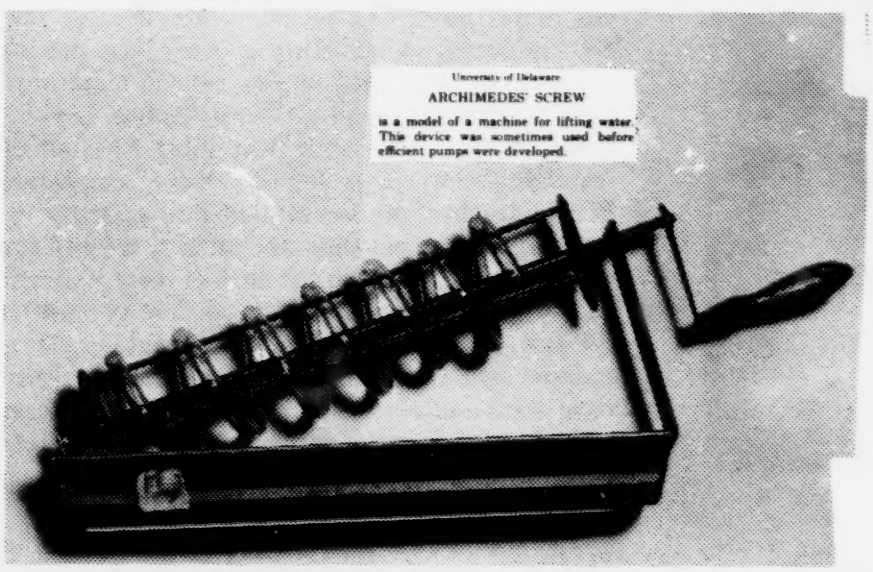

University of Delaware
ARCHIMEDES' SCREW
is a model of a machine for lifting water. This device was sometimes used before efficient pumps were developed.

**Figure 17.** Archimedes' Screw, 19th century, used at the University of Delaware. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

## SCIENCE

Demonstration apparatus had been prevalent in science teaching since colonial days. However, in most cases use of the material was motivated by assumptions about the nature of science rather than the nature of cognition. Scientific and mathematical apparatus could be found in the colleges primarily, but also in the small "vocational training" schools specializing in the teaching of practical mathematics such as that needed for accounting, surveying, and navigation. In the primary schools science teaching was practically non-existent for decades. There were exceptions: Neef taught an introduction to plant and animal life in the first two years; exposure to other natural phenomena—"air, wind, water and gravitation"—in the third; biology, physiology, and hygiene in the following two: physical geography in the sixth, and physics in the seventh (Monroe 1969). However, the leaders of American educational reform—men like Horace Mann, Henry Barnard, and George Bancroft, all of whom had followed MaClure's example in making the pilgrimage to Yverdon—only began to exert their influence in the 1830's.

The traditional college equipment included air pumps and hydraulic devices (Figs. 15, 16 and 17); electro-

static machines and meteorological instruments; telescopes and microscopes; models of the solar system and models of anatomy. There was apparatus for demonstrating the laws of mechanics, such as whirling tables, and simple machines–the lever, wheel and axle, inclined plane, pulley, screw, and wedge (Figs. 18 and 19). In addition there was a considerable amount of equipment used for actual scientific work as well as for teaching purposes. The use of observational instruments was particularly wided-spread. Until the latter part of the nineteenth century most of this apparatus was imported, although the same was not true of the instruments used by sailors and surveyors.

The growing emphasis placed on educational apparatus by the reformers brought with it an increase in the use of scientific apparatus as well as strong reactions against "teaching by machine." Henry Barnard and Horace Mann in particular used their legislative and administrative offices to insist on the acquisition and utilization of up-to-date equipment in the schools. The educational periodicals of the period reflect that ensuing conflict and also indicate what items of apparatus were considered essential or desirable. Thus, a lecturer on school furnishings and apparatus, after listing as essential the use of time-pieces, maps and globes, blackboards and numeral frames, proceeded to note the desirability of optical instruments, air-pumps and other pneumatic

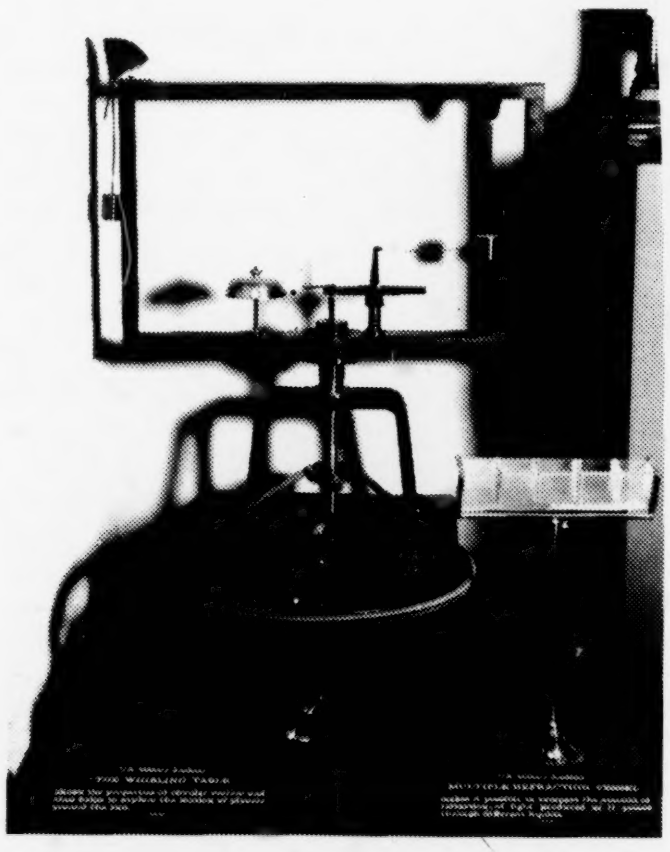


**Figure 18.** Whirling Table and Multiple Refraction Vessel, 19th century; used at the U.S. Military Academy. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

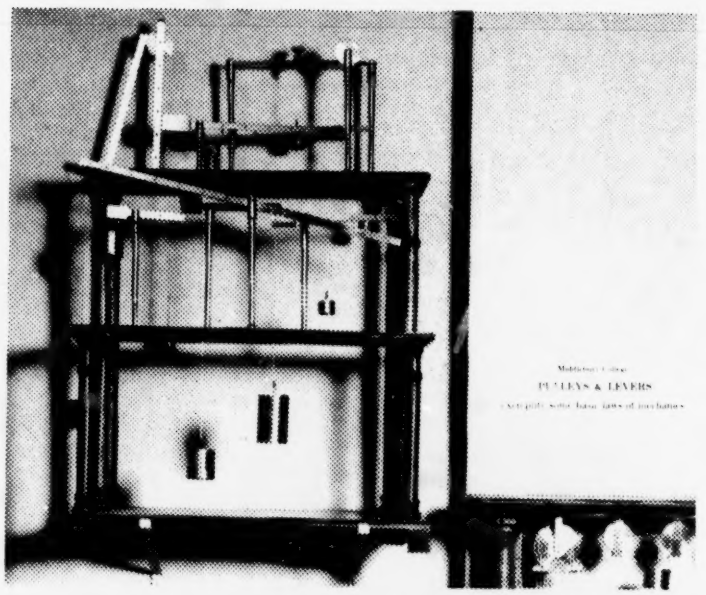



**Figure 19.** Pulleys and Levers, 19th century; used at Middlebury College. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

apparatus, and steam engines (Adams 1830). In the 1840's, more extensive lists could be found, suggesting, aside from texts and arithmetic charts with or without number frames, a variety of small globes; geographic, historic and even geological maps; mathematical drawing and measuring instruments as well as charts or models of geometric solids; astronomical models including planetaria, telluria, globes, and diagrams; and the standard static, hydrostatic and pneumatic devices as well as the use of prisms (Haskell 1841). Opposition to such extensive uses of equipment was voiced by those who decried the introduction of orreries, telluria, and expensive maps and charts, while advocating the intelligent use of standard maps and globes, recommended because the latter are "facsimiles in miniature of what they are intended to represent" and because they assist in acquiring knowledge in geography and science (Fleming 1841). More stringent opposition came from those who felt that the materials were either too expensive, or replaced the human teacher, or degenerated into gadgetry, particularly when teachers were not sufficiently well-equipped to use them. Although the first of these arguments was widely countered by emphasis on do-it-yourself devices, the last one was more difficult to refute, since teacher-training was a notorious problem, even in terms of the most restricted curriculum. It began to abate somewhat with the spread of the normal school and the professionalization of teaching in mid-century. One may speculate that the fact that the more elaborate equipment was largely imported served to strengthen the intermediate position of those who were not opposed to the use of equipment *per se* but wished to see it kept to a small number of relatively simple devices. For the same reason the establishment by the 1830's of a certain

amount of scientific nationalism (Miller 1965, p. 312) also would appear to strengthen this moderate position.

Among those who attempted to overcome the opposition to science teaching and to the related use of equipment were practising scientists. While some of their colleagues fought physically with members of the community over priorities in the use of telescopes, numerous astronomers increased the appeal of their subject by popular lectures, demonstrations and "evenings at the observatory."

Speaking before the American Institute of Instruction at Boston in 1841, A. Gray cited the following reasons for the study of science: First, that the natural sciences are "adapted to the order in which the faculties of the mind are developed"; secondly, that natural science is "especially fitted to form and cherish habits of patient observation and discrimination, and thus to keep all faculties in an active state"; thirdly, that "the study of nature will chasten the imagination and improve the taste"—he specifically sang the praises of nature studies for keeping children from daydreaming, or indulging in "somnambulic paroxysms"; fourthly, that "the study of the natural sciences will tend to develope and strengthen the moral sentiments and religious affection"; and, in fifth place, that the sciences have practical utility in commerce, agriculture, and the mechanic arts (Gray 1841).

Although contributing more to the growing enthusiasm for nature study than to the use of technological devices, Louis Agassiz's public relations work must be mentioned in this context. Not only did his public lectures have a broad appeal, but the nation-wide enthusiasm he engendered when he called upon the public to help him collect fishes in 1853 and turtles in 1855 (Lurie 1960, p. 188 ff.) could not but help have an impact on the pursuit of natural history in many regions of the country.

The rise of the high school after 1850 involved a broadening of the curriculum that helped to induce the gradual acceptance of science and scientific apparatus in the schools. Whereas there had been approximately 60 high schools in mid-century, the number increased by 500 percent over the next decade and rose to about 1000 by 1876 (Wesley 1957, p. 60). Subject to strong pressures from college curriculum, yet being in many cases adverse to the teaching of the classics—especially Greek—that this involved, many of these new high schools turned to the increasingly popular scientific subjects.

## ARTS AND SKILLS

The original Pestalozzian proponents of "object teaching" viewed this technique as something more fundamental than an aid to indoctrinating children with the content of the standard school curriculum. As noted in discussing the spread of scientific apparatus, those who favored the use of objects were frequently advocates for the broadening of the curriculum. These reformers sought in most cases to attain a better balance of the basic curriculum by expanding it to include some of the arts as well as training in manual or other physical skills. The last objective was, of course, complemented in the rise of manual and vocational training schools.

Music teaching provides an interesting example of the way in which curricular and methodological aims merged on occasions. In the 1820's, Lowell Mason was organizing singing classes for children, apparently unaware at first that in doing so he was promoting an activity dear to the heart of Pestalozzi and his American followers. Communication by means of articulation was a prime fundament of elementary training according to these men, and both Pestalozzi and Neef had regarded vocal music as an important means of acquiring good habits of articulation. When, about 1830, William C. Woodbridge brought these Pestalozzian notions to Mason's attention, Mason quickly embraced Pestalozzianism. Henceforth many of this prolific man's lectures and writings were directed to propagating ideas about music "on the system of Pestalozzi." Successful in introducing music into the curriculum of the public schools in Boston, Mason produced numerous books, guides, charts and other materials for music teachers. His publications, students, and direct influence served to have the Boston example followed so that music entered into the curriculum of school systems throughout the country. Mason's approach to note reading is significant in the present context: Children were taught a sequence of notes by rote singing; the teacher then pointed to the notes while they were being sung; only after this were the children asked to read the notes directly (Fig. 20).

**Figure 20.** "Diatonic Intervals" from Lowell Mason, *Musical Exercises for Singing Schools*, Boston, 1838. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

Lowell Mason's influence ranged over four decades. When, in 1865, at the age of 73, the "father of singing among the children (Rich 1946)" addressed the annual meeting of the National Education Association on the object method in music, the association printed his report as a separate pamphlet for wider distribution (Wesley 1957, p. 38). Miscellaneous inventions designed to assist in the teaching of music began to multiply after Mason's death in 1872 (U.S. Patent Office, Class 84/473 et al.).

The decade of the Civil War marks the spread of interest in object teaching on a national basis. The pioneering efforts of men like John Neef had become known mainly to those who either already shared the new views or were directly exposed to them. The reform ventures of the period from 1830 to 1860 also were largely regional, the preponderance of the discussions taking place in New England. Thanks, in part, to the formation of a national organization for educators (Wesley 1957), ideas concerning the utilization of objects were diffused more widely after 1860. Particular attention centered on the results being obtained at Oswego, New York. There, Superintendent of schools Edward A. Sheldon, impressed by an exhibition of educational devices in Toronto, had introduced Pestalozzian teachers, principles, and equipment to the schools. Demonstrations of work done at Oswego—including its normal school—and related reports and analyses appeared regularly in regional and national meetings and publications of educators.

Ideas on object teaching varied. The majority of discussants seem to have agreed that simply having an object in the classroom and showing it to the student did not constitute object teaching. Proponents of object teaching generally continued to stress that an object lesson must involve use of the senses supplemented by oral communication. However, there was strong concern that the object not be taken as an end in itself. Sheldon himself emphasized that the concrete object should be used only until a clear image of it had formed in the mind; from that point onward, the appeal should be made to this mental picture (Wesley 1957, p. 153).

The ideas of utilizing the object to gain an intermediate experience useful in preparation for encounters with some future reality was consonant with the development for training purposes of a variety of simulators. Thus, one finds an 1868 patent for a "device for teaching commercial transactions." This item simply consisted of a box with three compartments. A student training to become a cashier or teller used this box together with slips of paper that represented the transaction he was handling. The amount handed him was placed in one compartment; the amount due the customer was taken from the second compartment; the amount to be retained was then placed into the third compartment which represented the store or bank safe (U.S. Patent No. 74,740). The simulating principle was also at the basis of numerous devices for teaching physical skills. For example, an 1874 patent for an "apparatus for teaching the art of swimming" consisted of a contraption attached to the student that allowed him to make the permitted motions of arms and legs by having his hands and ankles attached to a set of movable levers while his trunk was supported in a fixed position (U.S. Patent No. 149,249).

## BEYOND SUBJECT KNOWLEDGE

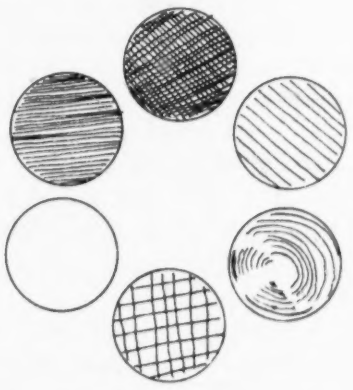
Most objects promoted for teaching purposes over the first half of the nineteenth century were designed to augment knowledge of a specific subject. The educators involved might stress the general applicability of the method used in a particular subject-related instance, or they might promulgate the idea that a specific subject was especially suitable for acquiring general learning habits, or they might simply subscribe to a general theory of the transfer of learning; nonetheless, in practice the learning process always turned out to be directed at acquiring a specified piece of information or a well-defined skill. The first notable effort to transcend this subject-bound attitude toward the augmentation of cognition is associated with the spread of the kindergarten movement.

Friedrich Froebel, the father of the kindergarten, was a German follower of Pestalozzi. He went beyond Pestalozzi or his other disciples in rejecting the use of books and formal study, however; and he was more insistent on the need for object training at an early age. Froebel was also quite specific in listing the objects to be used; but, because this list was attached to a philosophy that was rather comprehensive and complex, some confusion arose over the degree to which the specificity of Froebel's list of "gifts"—as his objects were known—should be maintained.

The concept of the kindergarten was brought to the United States after 1848. The first American kindergarten was founded at Watertown, Wisconsin, in 1856, when Carl Schurz and his wife, who had been a student of Froebel, settled there. This kindergarten was conducted in German, as were numerous others that followed in various parts of the country. Meanwhile, Elizabeth Peabody discovered that a play-school she had been conducting in Boston was essentially a kindergarten, and proceeded to acquaint herself with the principles of Froebel. The combined efforts of the German-American community and the New England reformers, aided by the support of individual administrators like W. T. Harris, superintendent of the St. Louis school system, led to a relatively rapid acceptance of the kindergarten system.

Froebel's twenty "gifts," intended to be used in the given sequence of ascending complexity, were as follows. The first was a set of six balls, made of rubber and covered with twine or worsted of different colors, but sometimes simply referred to as woolen balls. The second gift was a sphere, cube, and cylinder, made of wood (Figs. 21A and 21B). The third, fourth, fifth, and sixth gifts were four cubes, made up respectively of eight small cubes, eight oblongs, whole, half, and quarter "tubes," doubly divided oblongs. The seventh, eighth, and ninth were square and triangular tablets, staffs, and whole and half rings, all for laying of figures. The tenth, eleventh, twelfth, thirteenth, and fourteenth gifts were material for drawing, perforating, embroidering, cutting of paper and combining pieces, and for braiding. The fifteenth gift was slats for interlacing, and the sixteenth was a slat with many links. The remaining gifts—seventeen through twenty—were material for intertwining, paper folding, peas-work, and modeling (Wiebe 1869, pp. 6-7).

Some Froebel "Gifts"



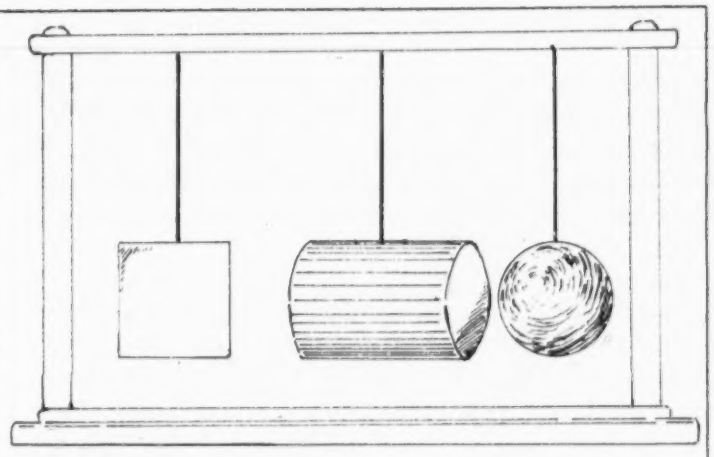


**Figure 21.**

There was considerable controversy among American kindergarten exponents whether to adhere strictly to the above list or whether to accept a broader interpretation that permitted the substitution of games and toys. Orthodox followers of Froebel opposed the substitution of ready-made toys largely because they felt these would counteract the natural drive for activity of the child. However, they were unable to stem the increase in educational toys and in patents issued for inventions concerned with kindergarten teaching (Fig. 22).

In emphasizing the use of specified objects for unstructured activity, kindergarten supporters took a major step toward utilizing the object to augment cognitive processes rather than factual knowledge. Much could depend on what happened to children after they were beyond kindergarten age. Among kindergarten supporters there were those, like W. T. Harris, who suggested children should shed the activities of the kindergarten when they left it, and proceed to the standard program and learning of the schools. Concerned followers of Froebel feared such "weeds of traditionalism" (Wesley 1957, p. 160) would crush the freshly planted seeds of progress.

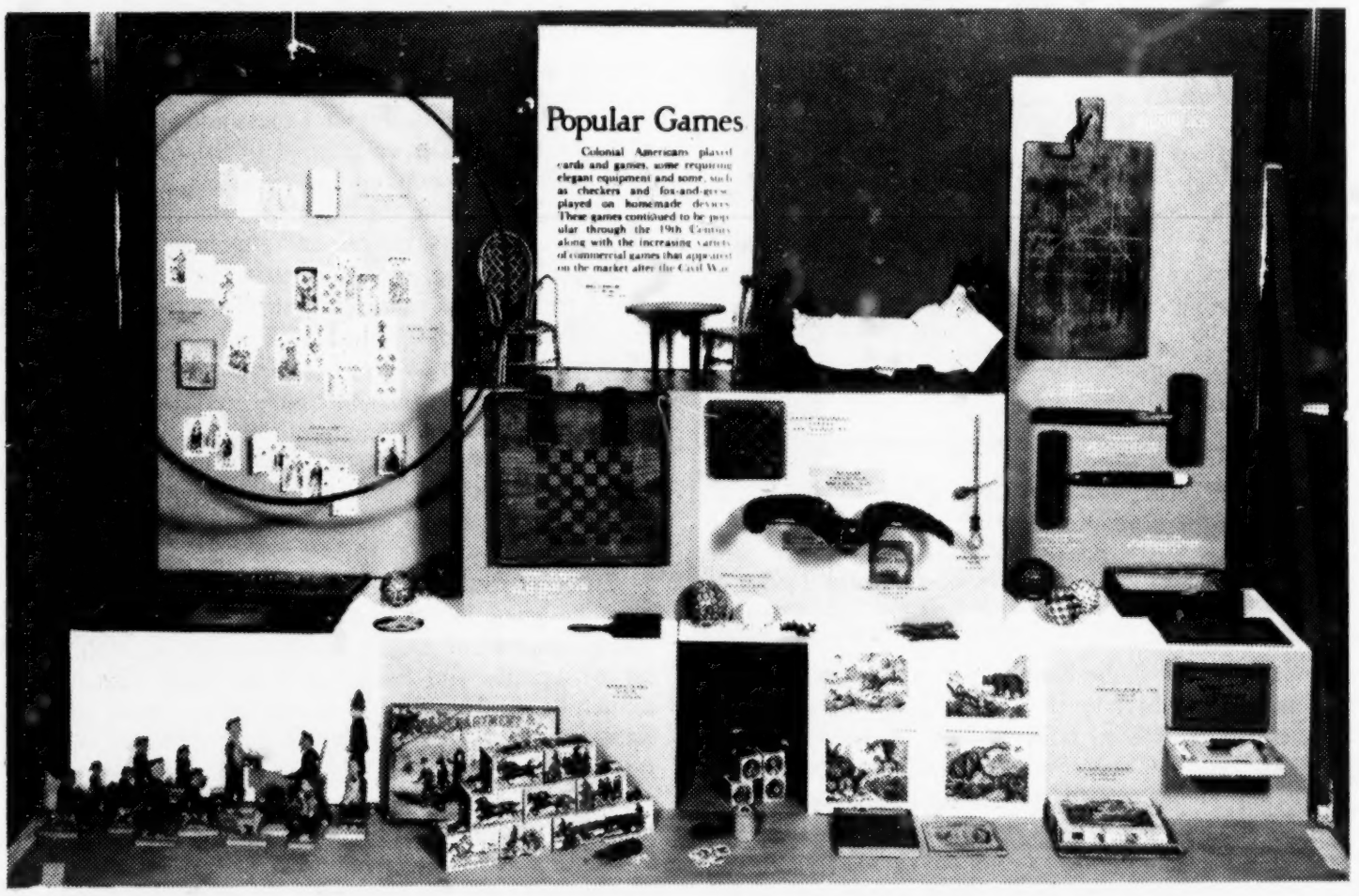



**Figure 22.** Popular Games Exhibit. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

## 2. 1876-1925: THE TECHNOLOGY OF PROCESSES

Cognition was still considered a mode of consciousness in the late nineteenth century. The concept of consciousness continued to change, however, and new techniques for studying it were developed, of which some promised to be more lasting than the various interpretations placed on the concept itself.

In the 1870's there was an increasing tendency to look upon consciousness as a process. There were fewer attempts to localize mental functions; the popularity of extreme doctrines such as that of the phrenologists, which stipulated 37 "organs" of the mind responsible for an equal number of mental faculties (Fig. 23), was waning.

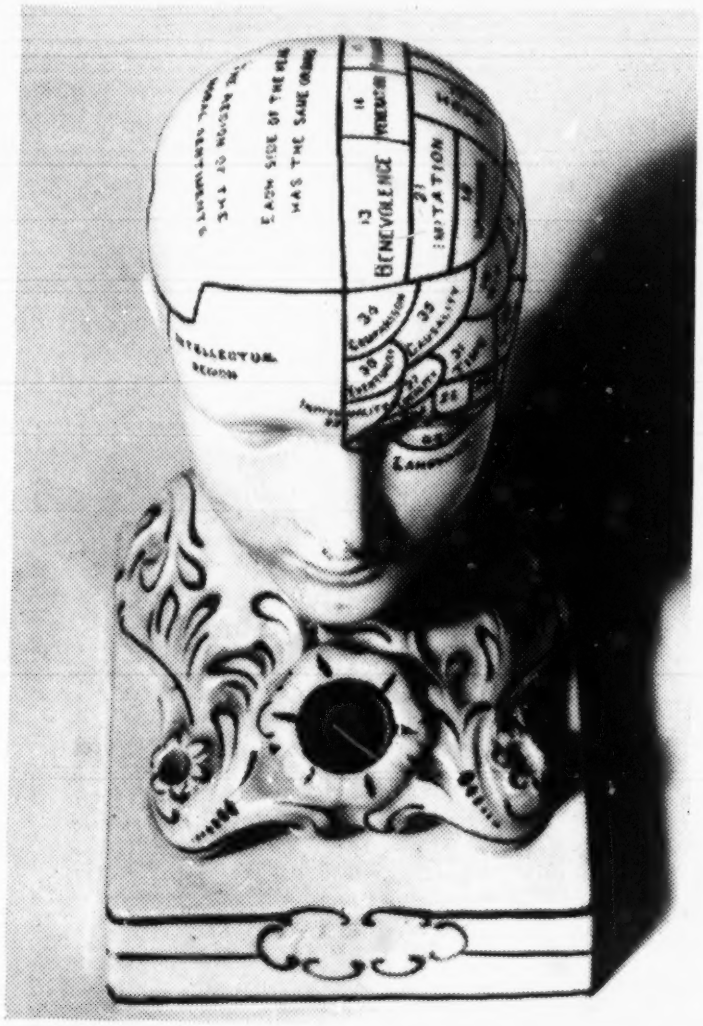



**Figure 23.** Phrenology Inkwell. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

In Germany, Wilhelm Wundt, whose American students included G. Stanley Hall, J. McKeon Cattell, E. W. Scripture, F. Angell, E. B. Titchener, G. M. Stratton, and G. H. Judd—to name only half of them—began to consider the analysis of the process of consciousness in terms of individual mental processes. In the United States, William James spoke of "the stream of consciousness" as something personal, mutable, continuous and selective. In addition, he postulated the functional nature of consciousness. As Boring (1929, p. 500) has noted, James's considering sensations as cognitive appears natural in the context of his functionalism: "It is plain that the principal use of mind to the organism is knowledge, and that knowledge about the external world (perception) is one very important kind of knowledge."

The school of thought formally known as "functionalism" was associated with J. R. Angell and John Dewey at Chicago. Perhaps its most widely read expression appeared in Dewey's classic paper (1896) on "The Reflex Arc Concept in Psychology." This was a strong statement against anything that seemed to go against the notion of a unified continuous process, whether such an implicitly dualistic model appeared as a hypothesis requiring an arc linking sensory and motor activities, or one treating stimulus and response as separate elements. Such separatism could be overcome by considering situations with regard to the function of the responses.

Whereas the position of functionalists tended to support work in "practical" psychology, namely educational and industrial psychology, this was not true of the "structuralist" stand. E. B. Titchener, the foremost spokesman of structuralism, felt strongly that it was not the business of psychologists to devote themselves to questions of learning or training for practical goals. According to him, it was the task of psychologists to apply scientific method to the study of human consciousness in order to determine the laws that govern the operation of the human mind. Psychology was to be a strictly experimental science in which the basic elements of consciousness were measured and their properties tested. Titchener adhered to the traditional division of the major units of consciousness and their basic elements: Perception, cognition, and emotion were composed of sensations, images, and affections, respectively. It is not surprising, therefore, that Titchener, after the initial exchange of polemics with the representatives of functionalism, should come to the support of his old teacher, Wundt, in 1909, by publishing an attack against the notion of 'imageless thought' propagated by members of the so-called "Würzburg school." The Würzburg group was not only suggesting the possibility of thinking without 'images' but of discarding the whole notion of 'consciousness' as the basis for psychological investigation.

Tiring of the numerous inconclusive experiments that were designed to settle such arguments, J. B. Watson, former student of Angell, in 1913 began to publish the set of articles and books that set forth the system known as "behaviorism." It marked the death of consciousness as the psychologist's subject matter, and of introspection as his method of observation. It permitted, indeed encouraged, the psychologist to be scientific, but stressed that he could accomplish this not by attempting to study sensations, images, or affections directly but rather by testing and measuring the responses made to a variety of given stimuli, thereby obtaining an analysis of the subject's behavior.

The divided positions among psychologists left the concept of cognition even more muddled at the beginning of the twentieth century than it had been before. It appears that the basic confusion, traditional in itself, became more noticeable in the United States with the shift in emphasis from attaining factual knowledge and adhering to established moral principles, to forming part of a larger process and interacting with one's environment. In order to learn something of attempts at technologically augmenting this elusive product or process called 'cognition' in the period before the impact of behaviorism came to be felt fully, it will be useful to view separately some efforts in the laboratory of the psychologist, the classroom of the teacher, the headquarters of the military man, the workshop of the inventor, and the exhibition hall claimed by historian, salesman, and propagandist.

## THE LABORATORY

About 1876, William James arranged a room for laboratory practice at Harvard; in 1879, Wilhelm Wundt in Leipzig established what came to be known as the first laboratory of psychology; and in 1883, G. Stanley Hall founded the psychology laboratory at the Johns Hopkins University. There were 25 laboratories for psychology in the United States before 1900; the number increased by another 10 before 1905. From that time on, the growth was more leisurely (Fig. 24).

For most of the first half-century of the psychological laboratory, psychologists were busily measuring and testing sensation, attention, reaction, memory and intelligence (Figs. 25 and 26). There was an obvious heavy reliance on the recently developed products of electrical, optical, and acoustical engineering; there was an intimate interrelation among the attainable precision of the instruments, with regard especially to the measurement of small quantities of time and motion, and the formulation and results of problems or experiments. Indeed, it has been suggested that the state of technology may have been a factor more significant in shaping the fate of psychological systems such as structuralism than has been realized so far (Popplestone and McPherson 1971).

To illustrate the type of technology involved it may be useful briefly to survey highlights from the development of one of the "bread-and-butter" instruments of the early psychology laboratory: the chronoscope. In addition, it will be instructive to consider aspects of the history of a device that has been acknowledged as having played a notable role in the formulation of a new theory and in the foundation of a new technology: the stroboscope.

The chronoscope is an instrument for measuring time intervals. The form of chronoscope first gaining widespread use among psychologists was based on that built by Mathias Hipp, a Reutlingen watchmaker, in 1842. It, in turn, was a modification of a chronoscope devised by Wheatstone two years earlier. In the 1840's, the

**Figure 24.** Psychological Laboratory Room, Harvard University, circa 1892. From Hugo Muensterberg, *Psychological Laboratory of Harvard University*, Cambridge, Mass., 1893. Photograph courtesy of the Smithsonian Institution.

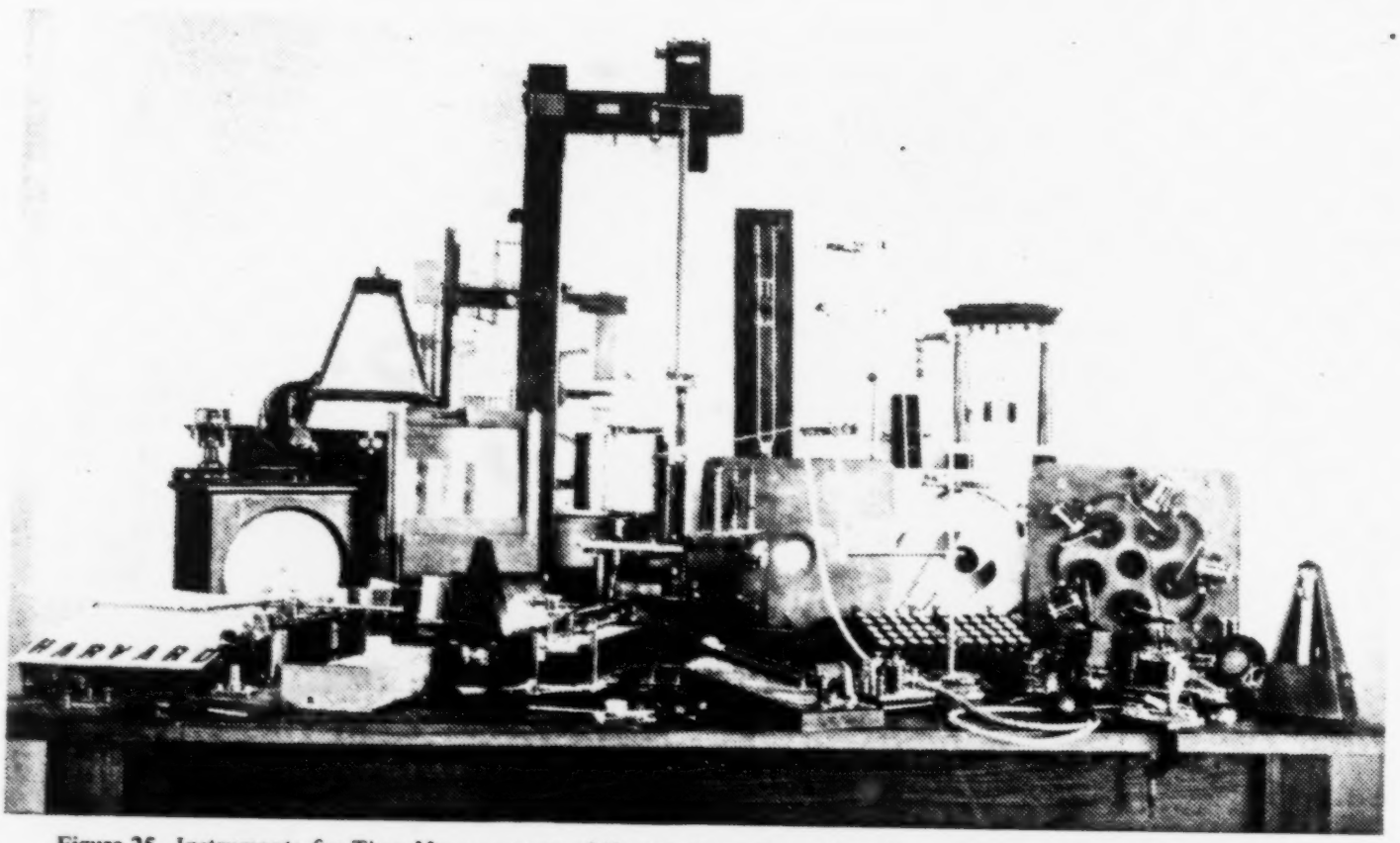



**Figure 25.** Instruments for Time Measurements of Mental Acts. From Hugo Muensterberg, *Psychological Laboratory of Harvard University. Photograph courtesy of the Smithsonian Institution.*

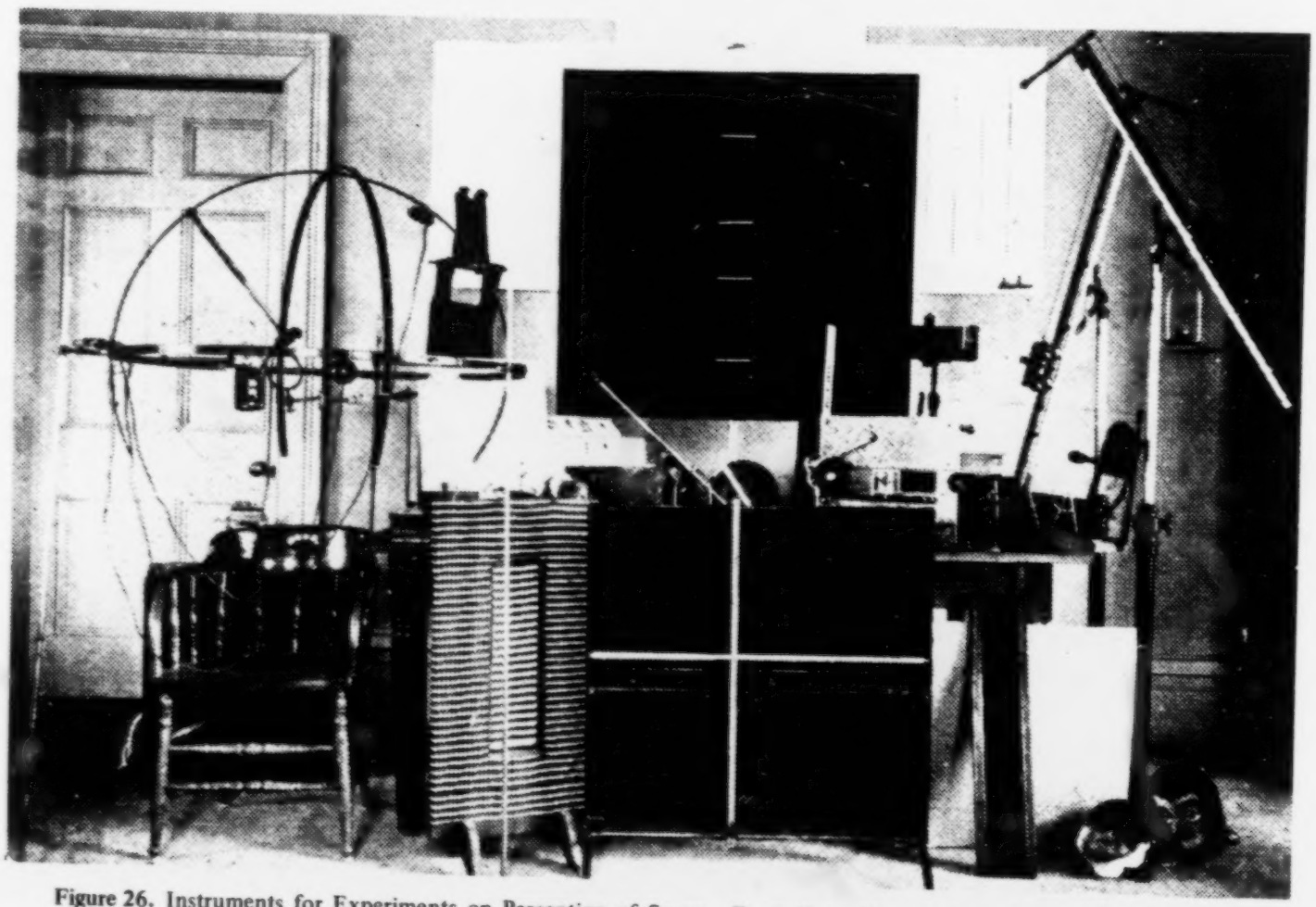


**Figure 26.** Instruments for Experiments on Perception of Space. From Hugo Muensterberg, *Psychological Laboratory of Harvard University. Photograph courtesy of the Smithsonian Institution.*

Hipp chronoscope was used widely for experiments on falling bodies. Early experimental psychologists, who subjected the instrument to various modifications, used it primarily for reaction-time experiments.

The Hipp chronoscope consisted of a weight-driven clockwork governed by a vibrating reed, and a gear train moving the hands that recorded the time interval in question (Fig. 27). The clockwork was stopped at the end of the time interval: A toothed wheel engaged by the reed was thrown against the gear train at the beginning and the end of the interval. This action was governed by one electromagnet in the earlier models, by two electromagnets in twentieth century models; in the earlier type, the clock moved only when the current was broken. Operation of the clutch mechanism and proper setting of the electromagnets was a major problem in both types (Titchener 1905, p. 112). Another difficulty, only partially overcome by placing the instrument in a case, was the noise factor. It has been noted that Helmholtz avoided both of these problems by using a galvanometer instead of the Hipp instrument (Woodworth 1938). The reed generally vibrated 1,000 times per second, so that the toothed wheel advanced one step in $^1/_{1000}$ of a second. There were usually two dials, the hand on one reading to $^1/_{1000}$ second, the hand on the other to $^1/_{10}$ second.

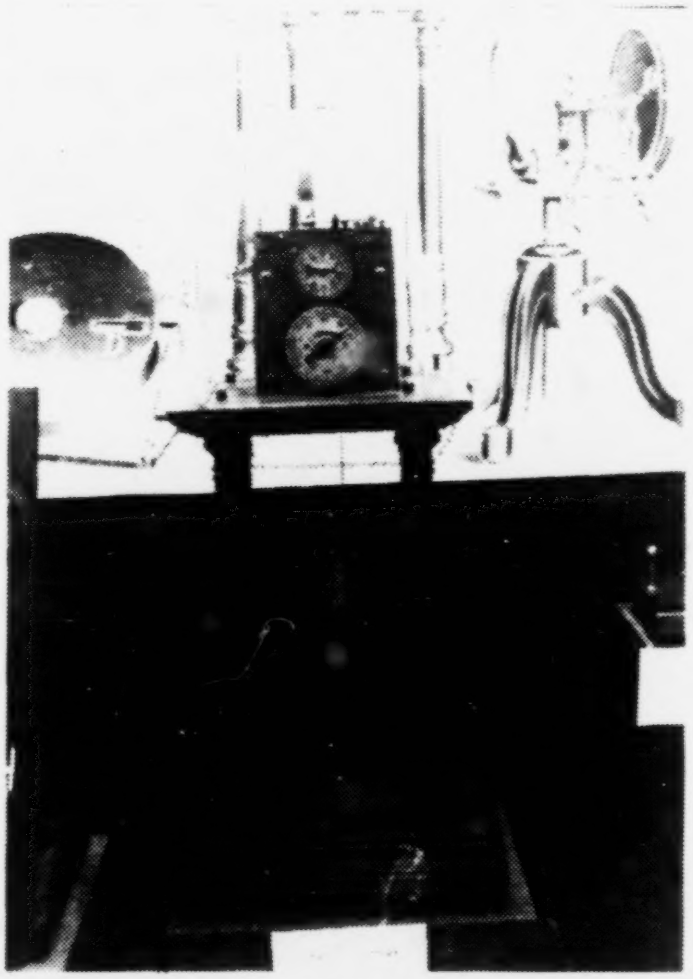


**Figure 27.** Hipp Chronoscope; used at the University of Michigan. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photograph courtesy of Archives of the History of American Psychology.*

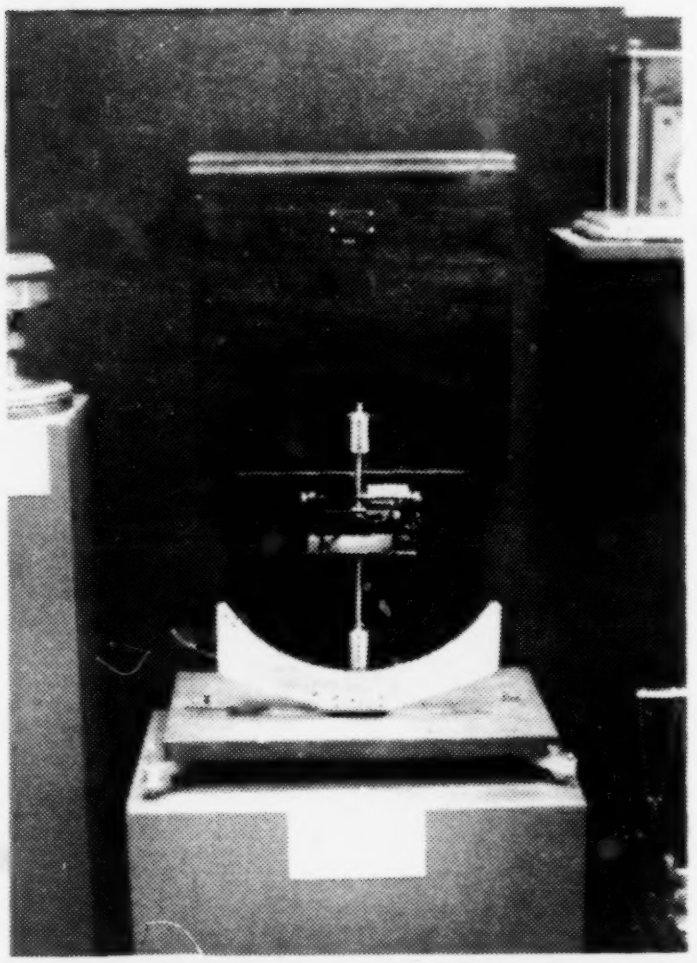


**Figure 28.** Bergström Chronoscope, by William Young & Co., Philadelphia; used at Pennsylvania State University. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photograph courtesy of Archives of the History of American Psychology.*

In 1905 Titchener listed four major varieties of chronoscopes besides the Hipp: One was the d'Arsonval instrument, based on a spring-driven clockwork; this read to $^1/_{50}$ second (Titchener 1905), but was soon refined to attain readings of $^1/_{200}$ (Zimmermann 1912). Another variety was the Ewald chronoscope, considered too fragile by some of Titchener's contemporaries; it also had the disadvantage, which persisted in later versions, of registering only hundredths of a second.

In addition to a wheel chronoscope, described by Cattell (1900), Titchener mentioned several pendulum chronoscopes. Some of these, such as the Bergström and the Seashore chronoscope, were used for decades, with suitable improvements incorporated over the years (Stoelting 1936). The Bergström instrument usually came on a base with leveling screws for zero adjustment of the indicator. A pendulum was mounted on a vertical frame which also held the indicator. The control by means of springs and electromagnets was similar in principle to that used in the previously described instruments. The time of swing of the pendulum could be varied by attaching different weights to the two ends; corresponding readings could be obtained by using the appropriate member of a set of interchangeable scales (Fig. 28).

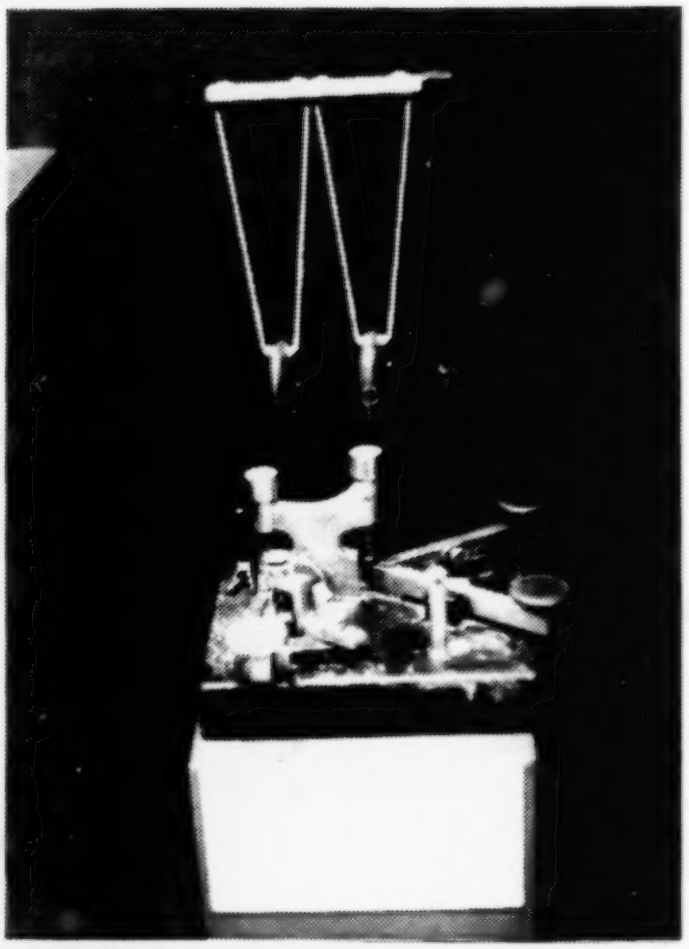


**Figure 29.** Vernier (Sanford) Chronoscope; used at the University of Akron, Akron, Ohio. *Photograph courtesy of Archives of the History of American Psychology.*

One of the chronoscopes that enjoyed wide use for several decades was the vernier chronoscope, the two main versions of which were also referred to as the "Sanford" chronoscope. This instrument used two pendulums of unequal length, swinging at slightly differing periods, usually set at .8 and .78 seconds. Thus, refined readings could be obtained on the principle of the vernier, long known for spatial measurements (Fig. 29).

An important development affecting the construction of most existing chronoscopes was the introduction by Dunlap (1917) of a synchronous motor in his so-called 'John Hopkins' chronoscope. Dunlap also replaced the troublesome springs, theretofore used to balance the electromagnet, by an armature (Dunlap 1918). Subsequent improvements in chronoscope construction reflect corresponding technological developments of the succeeding decades (Woodworth and Schlosberg 1954, pp. 12-13; Andrews 1948).

Quite a different device, particularly noteworthy in considering the influences that brought to prominence the concepts of motion and process in relation to cognition, is the stroboscope. The stroboscope creates an illusion of motion by successively presenting a set of images in rapid succession. The phenomenon in question has been known and discussed since antiquity. In the 1820's and 1830's it led to experiments with a variety of stroboscopic disks. About 1834, W. G. Horner in England, introduced a new form of stroboscope, the zoetrope (Michaelis 1958, p. 736). It was a device consisting of a horizontal wheel with a broad rim containing vertical slits on its circumference; the sequence of images was drawn on a strip placed inside the wheel (Fig. 30).

Stroboscopes played an obvious role in the developmen of cinematography. They have been of considerable importance in considerations of cognition as well. In a classic paper published in 1912, Max Wertheimer reported on a series of experiments he had performed on this subject of apparent visual motion. Among his specific findings was an analysis of the time interval between the exposure of two successive images. Considering a succession of vertical lines, he found that there are two limits in the interval span: One defines the impression of succession; the other, the impression of simultaneity. This result provided an important basis for further experimental studies. On a more general level, Wertheimer's stroboscopic studies, supplemented by the similar work of Kurt Koffka, led to the formulation of Gestalt psychology. The experience with the stroboscope supported the idea that perceptive phenomena cannot be explained satisfactorily by attempting to reduce them to certain basic elements, but that a perceptual field should be considered in relation to a dominant Gestalt (form).

**Figure 30.** Zoetrope (Stroboscope); used at the University of Nebraska. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photograph courtesy of Archives of the History of American Psychology.*

In reviewing the massive number of experiments conducted during the period under consideration, one finds conspicuously few efforts directed at technologically augmenting, rather than testing or observing, cognition. This may be attributed, in part, to the fact that the most detailed accounts of laboratory experiments and apparatus were compiled by men like Titchener and Scripture who were explicitly opposed to such an approach. However, there were some studies that are pertinent because the experimenters called attention to factors that were considered basic in the subsequent development of teaching and training devices. Among these we will single out certain experiments on illusions, on memory, and on fatigue.

At the turn of the century, there was considerable interest and experimentation in the subject of illusions, particularly geometrical illusions (Figs. 31 and 32). Some

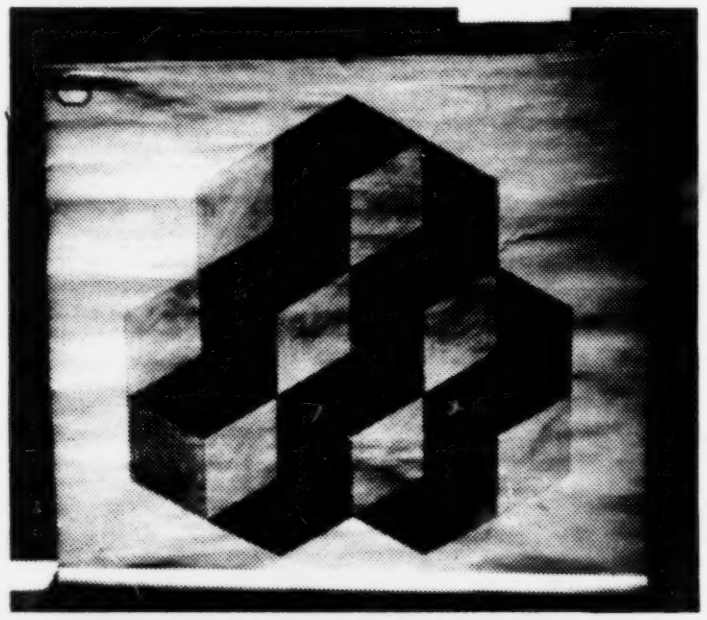


**Figure 31.** Illusions. Reversible block.

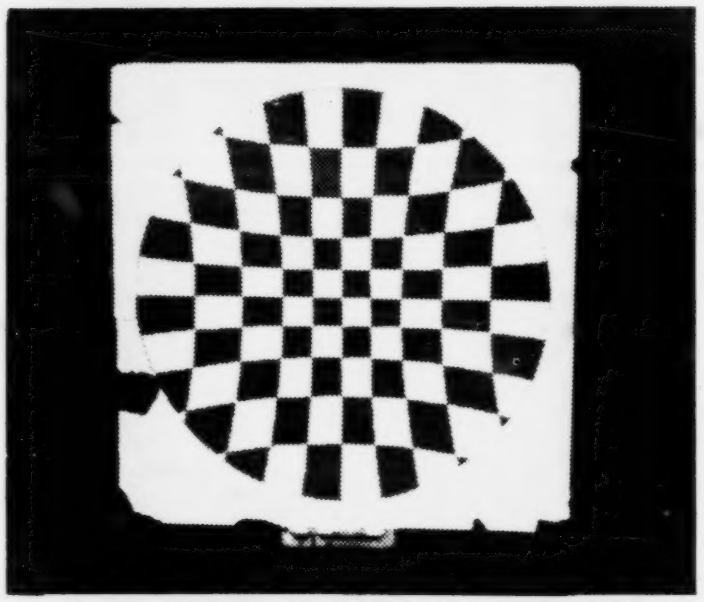


**Figure 32.** Helmholtz Chessboard. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photographs courtesy of Archives of the History of American Psychology.*

**Figure 33.** Müller-Lyer Illusion and Apparatus. *Redrawn from Woodworth (1954) p. 422.*

of these experiments continue to be of interest because of the lack of satisfactory explanation for the results. For example, in the 1890's it had been reported that practice with a given illusion diminished its effect (Woodworth 1954, p. 422). A number of American psychologists decided to test this application of the "practice makes perfect" principle. Judd, in particular, tested the effect in several studies on the Müller-Lyer, as well as the Poggendorff and the Zöllner illusion.

The Müller-Lyer illusion is the 'feather and arrowhead' illusion: Two equal-line segments appear unequal as the result of attaching to the ends of each one a pair of short line segments, making acute and obtuse angles respectively with the original two segments. Judd used the following apparatus (Fig. 33): A wooden frame contains a card or sheet of paper on which is fixed one of the line segments. A sliding board, attached to a guide rail that is operable by the subject contains the second segment; this segment is so aligned that it is superimposed on the first segment as the board is moved. The subject's task is to adjust the sliding board until he thinks the two line segments are equal. The setting is recorded by pressing on a pin attached to the sliding board: This pin leaves a set of holes on a ticker tape hidden from view of the subject: One is a double hole and is in a fixed position; the other one is a single hole whose position depends on the position of the movable pin. The distance between the double and the single hole is measured to determine the amount of the illusion.

In one of Judd's experiments, the subject made 25 settings per day for 24 days; at the beginning the line segment, making oblique angles with its two pairs of end segments, was made approximately 17 percent shorter than the line making acute angles with the end pairs. At the end of the 600 trials, the difference was about 2 percent. However, when the position of the lines was reversed, the subject reverted to larger error, which was then reduced again at varying rates. These experiments led to a great deal of discussion because they were conducted in such a manner that the subject had no—or, at best, very fragmentary—knowledge of his results (Woodworth 1954, pp. 422-423; Annett 1969, pp. 68-69, 146-147).

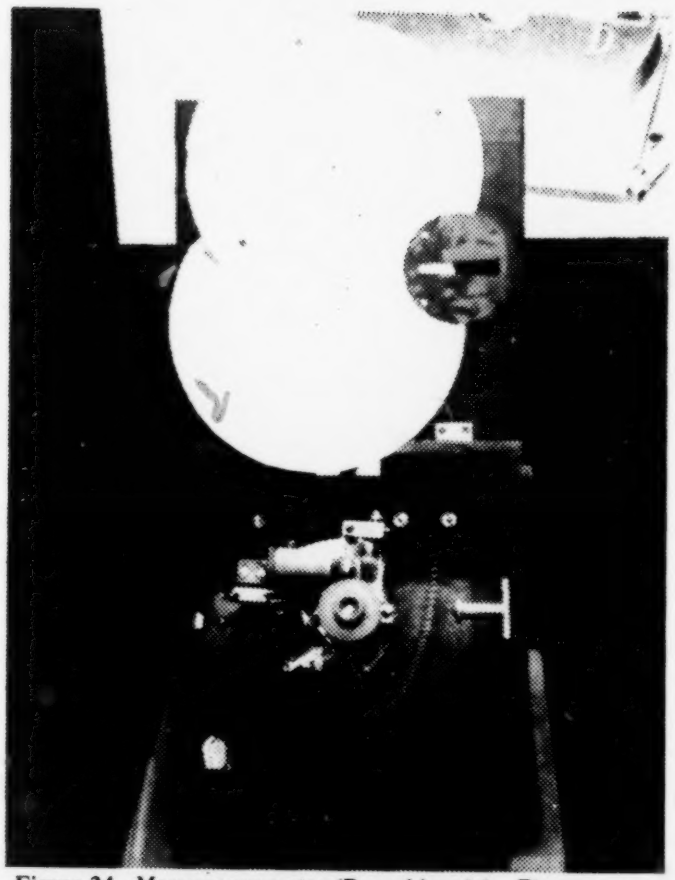


**Figure 34.** Memory apparatus (Ranschburg) by Zimmermann, Leipzig (showing disks); used at the University of Michigan.

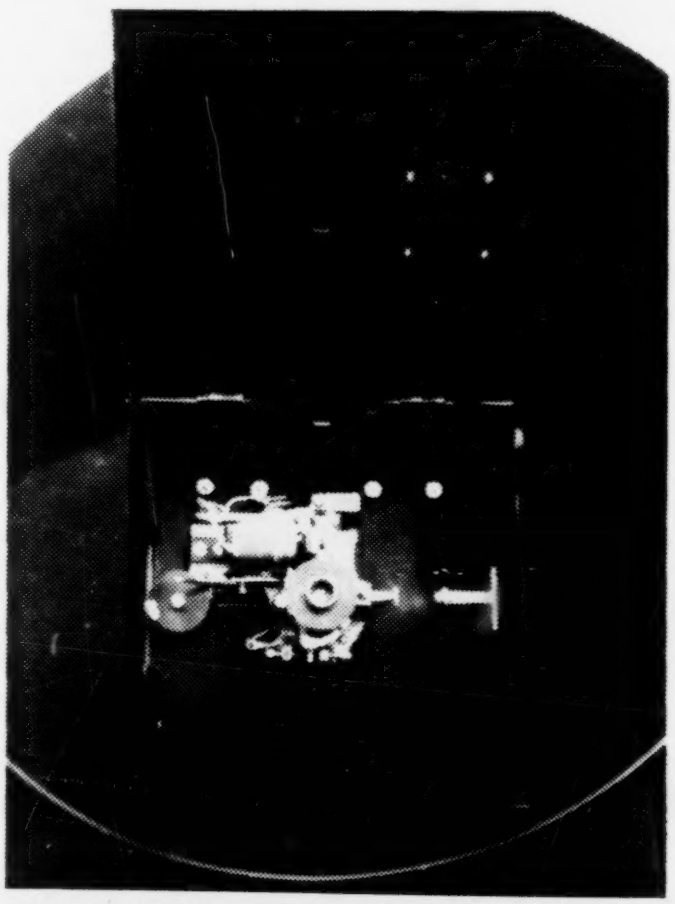


**Figure 35.** Memory apparatus shown in Figure 34, without disks; used in Ohio. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photographs courtesy of Archives of the History of American Psychology.*

Memory studies were put on a sound experimental basis with the publication in 1885, by Hermann Ebbinghaus, of a work that has been called "the pioneer experimental study on the whole field of learning, retention, and remembering (Woodworth 1954, p. 695)." To avoid the influence of prior associations held by ordinary words, Ebbinghaus introduced nonsense syllables. Having devised over two thousand nonsense syllables by a combinatorial method subsequently refined by other investigators, Ebbinghaus read the list of syllables at a rate of two-fifth seconds per item, timing himself with metronomes and stop watches. To avoid the possibility of forming associations by seeing several things at the same time, subsequent investigators pasted the list on a covered drum that rotated, exposing one syllable at a time through a slit in the cover (Müller and Schumann 1894). The concept of the rotating drum was modified when it was found that constant rotation was hard on the subject's eyes.

Various instruments with stepped motion were devised, among which one of the most widely used was the Ranschburg (1901) apparatus in which the syllables are printed on circular cards, and placed inside a covered disk having the usual slit for viewing individual syllables (Figs. 34 and 35). The cards are rotated by stepped action of an electromagnet. The apparatus was available in various versions, some of the more complex allowing interaction with metronomes and chronoscopes, and having variable time spans. Although much of this equipment was imported, various forms of memory apparati were made in the United States. They ranged from home-made or simply manufactured card-changers (Fig. 36) to more complex devices permitting projection for simultaneous viewing by members of a class (Stoelting 1936).

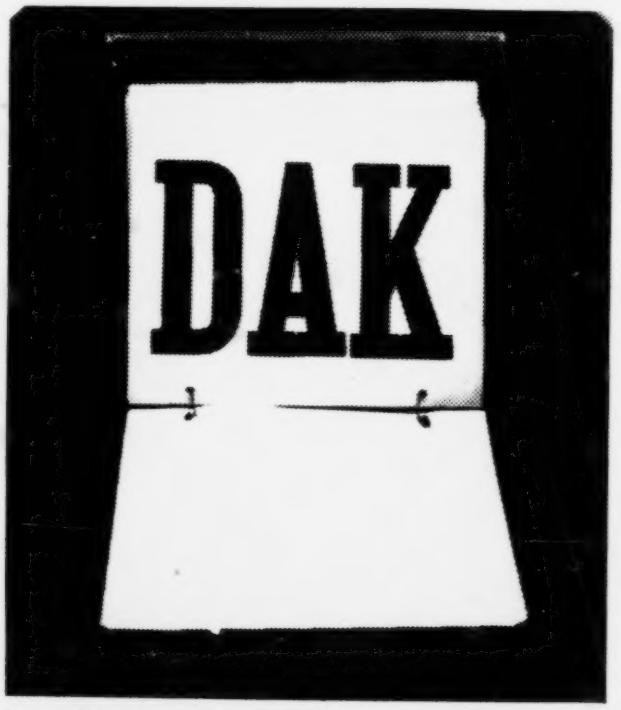



**Figure 36.** Memory device for nonsense syllables; used at the University of Illinois. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photograph courtesy of Archives of the History of American Psychology.*

Among the studies initiated by Ebbinghaus and pursued by subsequent European and American investigators were those dealing with 'memory span'. Ebbinghaus found that he could recall up to seven syllables after the first try, but that it took him fifteen repetitions to learn twelve syllables, and fifty to learn thirty. He studied the effect of the length of a practice session, and determined that for the type of rote learning involved in his memorization of nonsense syllables it was more effective to operate by 'spaced' rather than 'continuous' repetition. He also spent a considerable amount of time on the subject of 'over-learning'—obtaining a relationship indicating that retention is roughly proportional to the amount of learning. These are but a few samples of work that were distinguished by the combination of innovative ideas and good statistical techniques.

One of the early studies of particular interest for later work on training devices was an experiment on fatigue conducted by Arps (1917; 1920) that involved use of an ergograph. The ergograph is an instrument that gives a graphic record of the work produced by a specific muscle system while other parts of the body are immobile (Figs. 37, 38). The traditional ergograph involves use of a finger. The subject places his hand and lower arm on a hand rest designed to keep all parts of the hand, except for the working finger, from moving; the finger is attached to a wire from which is suspended a weight that is to be lifted. The wire is attached to a movable carriage which has a pointer recording the movement on a kymograph drum. (The kymograph is the standard device for recording, graphically, results of psychological and physiological processes; a simple kymograph consists of a rotating drum covered by paper, (Fig. 39)). In the Arps experiment three subjects were required to lift a nine-pound weight by the middle finger. Sometimes they could see the kymograph record while they were working: at other times it was hidden from their view. Arps found a significant difference in performance, the knowledge of their results increasing work output by 5 to 35 percent (Woodworth 1954).

**Figure 37.** Ergograph by H. Diel, Leipzig; used at the University of Michigan.

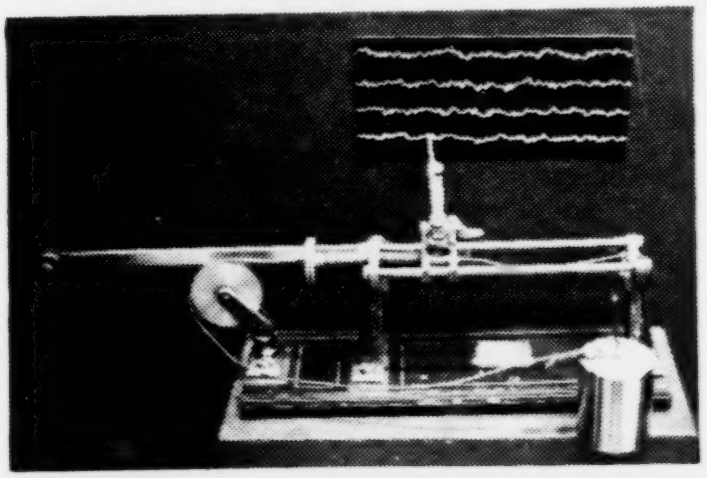


**Figure 38.** Ergograph by E. Zimmerman, Leipzig; used at the Ohio State University. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photographs courtesy of Archives of the History of American Psychology.*

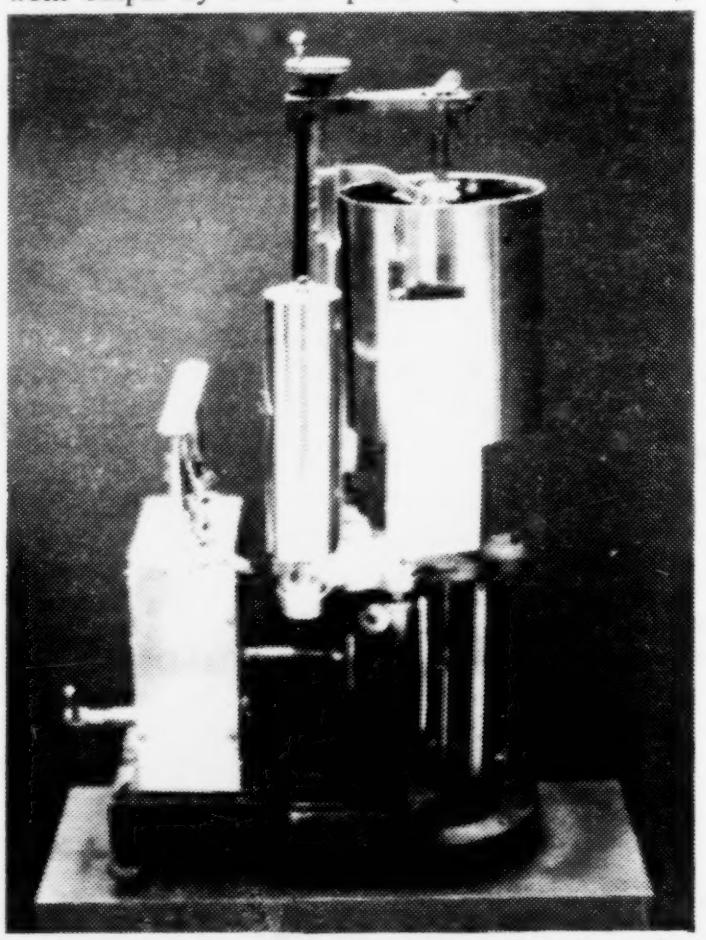


**Figure 39.** Kymograph by E. Zimmermann, Leipzig; used at the University of Michigan. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photograph courtesy of Archives of the History of American Psychology.*

## THE SCHOOL

Toward the end of the nineteenth century, American educators came under the influence of the Herbartian movement. Herbart had a belated following in Germany after his death in 1841; Americans who visited abroad returned with so much enthusiasm for his doctrine that a National Herbart Society was founded in the 1890's which exerted considerable influence. There was much emphasis on making the curriculum interesting and on interrelating the subjects taught, choosing one as a core subject. Methodologically, the teacher was expected to follow the five steps of preparation, presentation, asso-

ciation, generalization, and application. Among the opponents to Herbartianism were the followers of Froebel who found the new doctrine too restrictive. Others who disagreed with the movement were William James and John Dewey.

Other significant educational currents about the turn of the century included the child-study movement, championed by G. Stanley Hall, which appeared to turn many parents and teachers into laboratory workers, and children into laboratory subjects, presumably thriving under the unusual individualized attention they were receiving. At the same time, there was the learning-by-doing movement, in rather close accord with the ideas of John Dewey, who was conducting his own laboratory school before leaving Chicago for Columbia University in 1904.

In 1903, E. L. Thorndike published his first book on educational psychology. This marked the beginning of an era in which the "connexionism" of Thorndike was to become one of the most powerful theories in American education. Thorndike had studied under William James at Harvard, where in 1898 he had published his famous thesis on animal intelligence. Under the urging of Cattell, then engaged in work on mental tests and individual differences, he extended his researches to questions of human intelligence and learning. In the 1903 work there appeared statements that foreshadowed some of the subsequent thinking of the twentieth century. Discussing the need for measurements, Thorndike observed that the "work of education is to make changes in human minds and bodies (Thorndike 1903, p. 3)." He considered the mind as a "host of highly particularized and independent abilities" and considered the world as affording the stimulus required "for the more primitive and fundamental traits in human nature (p. 45)." Observing, on the basis of statistical analyses, that moral traits are more easily influenced by the environment than matters of intellect and efficiency, he suggested that educational theorists worry less about the "development of powers and capacities" which "is the one thing that the schools or any other educational forces can do least (p. 46)" and concentrate instead on "the three chief practical problems of education . . . those of hygiene, of opportunity, and of incentives and deterrents (p. 79)."

Subsequently, Thorndike detailed the basis of his "connexionism," namely, the idea that psychological processes consist of connections between stimuli and responses. Most important for learning theory and studies of learning by machine was Thorndike's Law of Effect, which in its original statement of 1911 read as follows:

> Of several responses made to the same situation, those which are accompanied or closely followed by satisfaction to the animal will, other things being equal, be more firmly connected with the situation, so that, when it recurs, they will be more likely to recur; those which are accompanied or closely followed by discomfort to the animal, other things being equal, will have their connections with that situation weakened, so that, when it recurs, they will be less likely to occur. The greater the satisfaction or discomfort, the greater the strengthening or weakening of the bond (Thorndike 1911, p. 244).

While these theories and ideas were being disseminated among teachers, the schools slowly reflected the advances of technological developments in the world at large. Standard equipment changed in appearance: Blackboards were no longer plain wooden boards, but either had a slate surface imposed on the board, or consisted of hyloplate, that is, two boards pressed together; eventually, the slate replaced the wood. In time, school rooms had pictures and bulletin boards, replacing some of the traditional blackboard space. The slates and slate pencils used by pupils gave way to paper and lead pencils as paper became cheaper, and lead pencils, first manufactured in the United States in 1861, became more easily available. Steel pens, the use of which had been increasing since the Civil War, were supplemented by fountain pens, although their use did not spread until the 1920's. Ink manufacture began to develop among specialty companies. Primary school accessories showed the influence of the broadly interpreted kindergarten movement with increasing use of alphabet blocks, pegboards, modeling materials, and the like. Various color printing developments increased the appeal of books and magazines. The use of scientific apparatus spread (Figs. 40, 41); and, more significantly, introduction of laboratory courses in the 1880's changed the application of such equipment: It no longer served purely for demonstrations in the primary and secondary schools but for actual practice in performing—or at least repeating—experiments. The magic lantern became a popular visual aid in school as well as in the home (Fig. 42).

In the early 1900's a few people considered the use of motion pictures for education purposes. A number of men began to compile catalogs of available films that could be considered "educational." In 1910, Rochester, New York, included films in its public school programs. Other cities followed, although somewhat reluctantly because the expense and bulkiness of the equipment, as well as the potential fire hazard, presented large obstacles. Over the next decade numerous commercial companies sprang up that specialized in educational film rental and in streamlining the equipment and increasing its safety. Thomas Edison helped the cause by public statements to the effect that "books will soon be obsolete in the schools. Scholars will soon be instructed through the eye. It is possible to teach every branch of human knowledge with the motion picture. Our school system will be completely changed in ten years (Saettler 1968, p. 98)." Despite such enthusiasm there was surprisingly little effort to gear the content of the films to educational needs by taking into consideration any of the prevalent notions concerning learning. To be considered educational, it was usually enough that a film treated a subject having some bearing on the curriculum, so that many educational films were simply commercial entertainment films, or advertising products, with or without some modification or cutting.

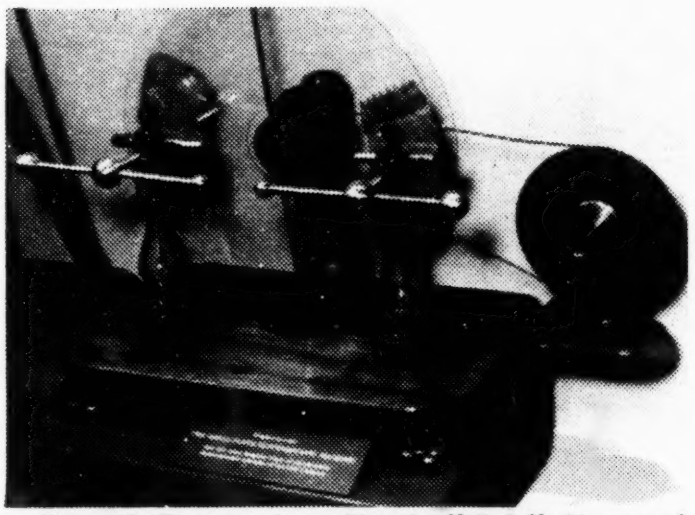


**Figure 40.** Electrostatic machine, by Hall & Harbison; used at Rutgers University. *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

**Figure 41.** Demonstration Eye, by C. Gerhardt, Bonn; used at Colgate University. *National Museum of History and Technology. Photograph courtesy of Smithsonian Institution.*

### THE BARRACKS

Among the various training techniques that had been developed for the military in World War I was the use of films. It was apparently more successful than the attempts to use film in the public schools; eventually, the old war films were distributed to school system extension divisions by the U. S. Bureau of Education (Saettler 1968, p. 114).

Of various ordnance trainers developed at this time, one has been referred to frequently in recent years. This was a device designed to teach soldiers to squeeze a rifle trigger instead of jerking it. A pressure tambour attached to the trigger mechanism was connected to a manometer by a rubber tube. Liquid in the manometer moved slowly when the trigger was squeezed, but was disturbed when the trigger was jerked. The soldier, thus, was informed of his results, with apparently gratifying consequences (English 1942).

Despite examples such as this, the main contribution of psychologists in World War I lay in testing rather than training. The famous Army Alpha and Beta tests, devised under the leadership of R. M. Yerkes and a team of psychologists, not only provided a very effective means of rapidly testing large groups of literate and illiterate soldiers as to their ability, but in a sense obviated the need for certain types of immediate training. The work done served to call attention to the potential usefulness of psychologists in the field of tests and measurements, resulting in the tremendous increase of activity in this field within industry, government, and university in the nineteen-twenties and thirties.

### THE WORKSHOP

Some of the most interesting devices of this period that may be considered genuine contributions to the technological augmentation of cognition were inventions, made by various individuals, that did not achieve much success.

In the 1880's, numerous inventors began to file patents for "automatic teachers" of one form or another. Among these patents is one interesting item, invented by Ira S. Kinck of New York. In his patent for an educational apparatus, granted in December 1884 (U.S. Patent No. 309,064), Kinck described his invention as ". . . involving any suitable mechanism whereby a signal will be given whenever the proper answer to a question is selected." The device, whereby the inventor hoped to make the education of children "easy and interesting," consisted of a set of questions and answers, and an auditory, visual or audio-visual signal which informed the user when he had given the correct answer, thereby "[supplying] the place of the teacher." The inventor stressed that such a device would be useful in adult education as well as in teaching children.

Among the inventors of educational devices in this period is the well-known Maria Montessori, who, in 1914, obtained an American patent for training the sense of touch (Mellan 1936; U.S. Patent No. 1,103,369). She has also been credited with introducing one of the first

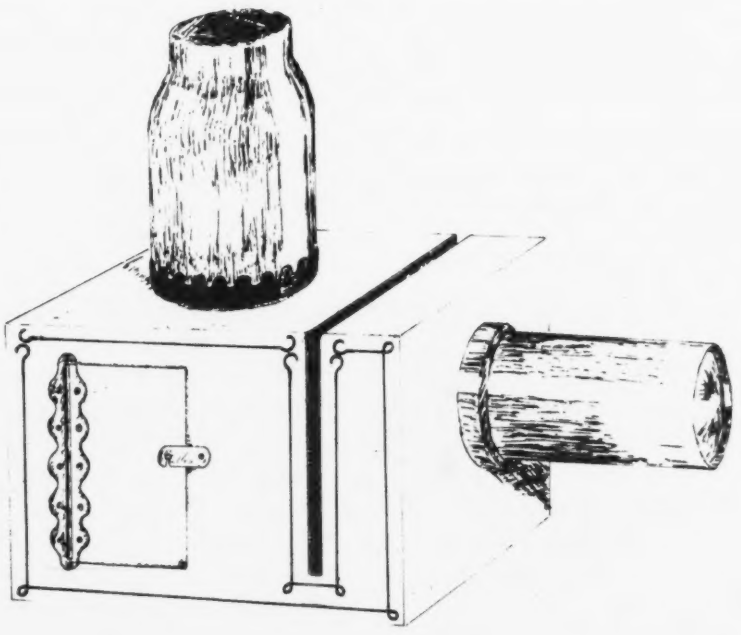


**Figure 42.** Magic lantern.

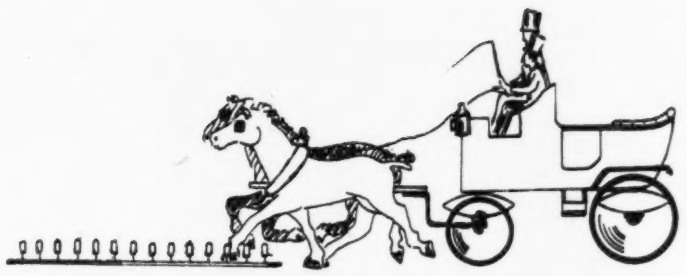


**Figure 43.** Twombly's "Carriage driving detector." *Based on U.S. Patent No. 280,535.*

feedback devices: She suggested giving children a set of wooden blocks with holes of varying diameters, along with cylinders to be fit into the holes. When a child tried to fit a wrong cylinder into a hole, it would not be able to fit in the others, thus obtaining knowledge of his success or failure from the blocks (Montessori 1912; Saettler 1968, p. 61).

Mechanisms that found fairly wide-spread applications included a number of inventions designed to assist in the training of typists and telegraph operators. Many of these were simple types of simulators without feedback features.

Other inventions of the period included a series of simulators designed to train drivers of land vehicles as well as airplane pilots. Thus, one finds an 1883 patent for a "carriage-driving detector," (Fig. 43) designed to train people in driving a carriage in narrow alleys or pathways (U.S. Patent No. 280,535). After 1910, there were an increasing number of patents for airplane trainers and testers (U.S. Patent Office, Class 35/12) and after 1915 the number of automobile driving aids increased as well (U.S. Patent Office, Class 35/11). It should be noted, however, that many of these inventions were simply devices for placing the vehicle to be driven in such a position–in a frame, for example–that the trainee could go through the motions of driving by running the motor, and obtaining simulated responses, without actually moving the entire vehicle (U.S. Patent Nos. 1,007,445; 1,161,920) (Figs. 44, 45). More elaborate simulators that relied on audio-visual aids and incorporated feedback signals did not make their appearance until the 1930's.

## THE EXHIBITION HALL

In the second half of the nineteenth century and in the early years of the twentieth century one of the most effective and widely used means of diffusing information concerning new technological devices was participation and display in national and international exhibitions, as well as in regional fairs and local museums (Fig. 46). This applies particularly to technology pertaining to the augmentation of cognition. Educational exhibits could be spotted at the Great Crystal Palace Exhibition in London of 1851; they were present in succeeding International Exhibitions in Paris, London, Vienna and Philadelphia.

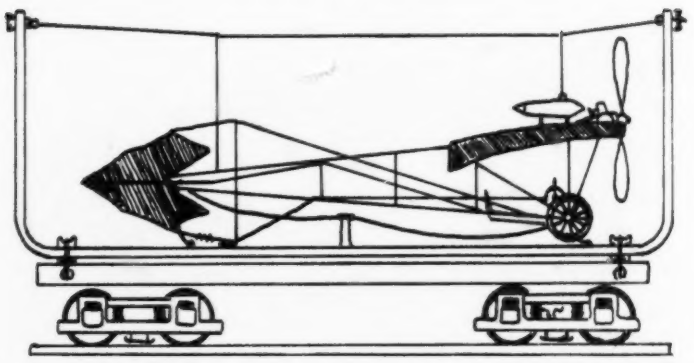


**Figure 44.** W. F. Mangels' "Means for Teaching Aviation and Testing Aeroplanes." *Based on U.S. Patent No. 1,007,445.*

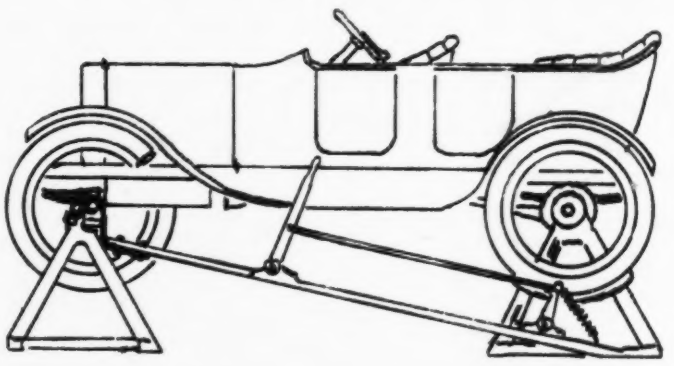


**Figure 45.** C. M. Bishop's "Mechanism for Testing and for Instruction in the Operation of Automobiles." *Based on U.S. Patent No. 1,161,920*

The Philadelphia International "Centennial" Exhibition of 1876 is of particular interest in showing what the United States, which had received praise for a number of educational items at the 1873 Vienna show, presented to the world on "home grounds." Its content is of additional significance for a study of the fifty-year period after 1876, because many of the educational exhibits found their way into national and regional museums and departments of education.

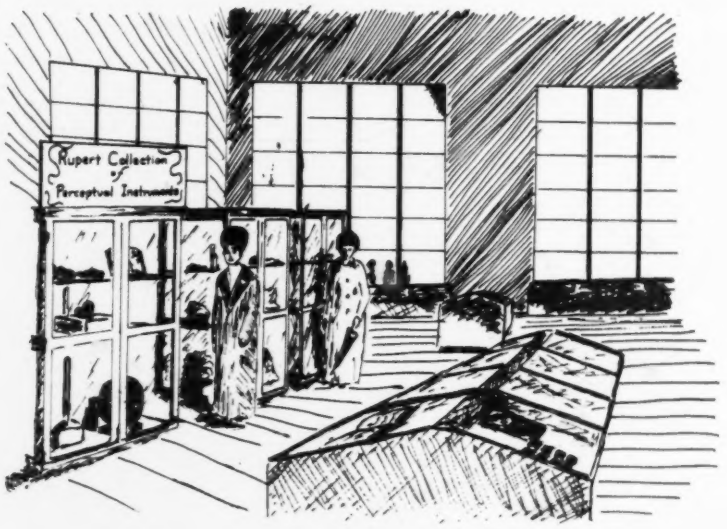



**Figure 46.** An exhibition.

Education and Science were combined as one department in the classification of the 1876 exhibition. Numerous items in the sub-category "Scientific and Philosophical Instruments and Methods" were advertised for use by students and teachers, whereas entries in the sub-category of "Educational Systems, Methods, and Libraries" were dominated by books. However, there was a representative cross-section of other "educational" objects. Recent innovations in blackboards were stressed by exhibitors who showed off liquid blackboard slating; blackboards on wall, cloth, and paper; and adjustable blackboard frames. Maps and charts were widely featured, along with accessories such as map rollers and map cases. Several companies emphasized or restricted themselves to their specialties: H. B. Nims & Co. of Troy, New York featured terrestrial and celestial globes; E. Steiger of New York stressed kindergarten material, while offering school devices including not only globes but an "automatic tellurian." The contributions of some of the State educational departments are of particular interest: Among them there were various photographs of blackboard work; numerous examples of botanical and zoological specimens prepared by pupils; examples of kindergarten work; "chemical products" by college students; and mechanical contrivances constructed by school children (U.S. Centennial Commission 1876, pp. 257-61).

The judges were extremely critical in their over-all evaluation of the United States educational exhibit, expressing regret at the lack of participation as well as the lack of quality that the host country had demonstrated (U.S. Centennial Commission 1880).

The World's Columbian Exposition held at Chicago in 1893 was also of special interest in the present context. There, two rooms were provided for a section of psychology. One of these served to show a typical laboratory of psychology. The other one contained apparatus used "in the experimental study of mental phenomena (Jastrow 1893)." In conjunction with the latter, there was an area set aside to illustrate studies concerning the growth and development of children, with particular reference to matters pertaining to the growth of mental processes. The material consisted largely of various anthropometric data with considerable emphasis on comparative statistics collected in various urban centers, such as Boston, Toronto, Worcester, and St. Louis. The significance of these data seems to have appeared questionable even to the exhibitors.

Despite the variations in quality of exhibits related to learning and cognition, exhibitions such as those named had a noticeable effect, by calling attention to the availability and usefulness of new technological products, and by directly making available to appropriate institutions some of the items in question, thereby translating their impact to specific locales. They also served to increase the growing advertisement effectiveness of manufacturers of educational and psychological devices.

During the same period, museums contributed greatly to these efforts. Among the increasing number of new museums that were founded between 1876 and 1925, there were quite a few children's museums and educational museums. In addition, the major art galleries and science museums developed programs designed to bring more closely together the exhibit hall, the visitor, and the displayed object. Such programs included museum lectures; gallery talks; structured extension and class work in adult and children's education, as well as teacher training; and field trips. Museums served not only by drawing on objects in their collections to augment public cognition—they also took the lead in utilizing the technology of new media. Thus, in 1923, the Brooklyn Children's Museum and the Smithsonian Institution pioneered in the use of radio broadcasts for "educational" purposes (Ramsey 1938, p. 194). Even though there had been earlier experimental stations at several colleges and universities, regular educational programming had begun in scattered fashion only during the previous year (Frost 1937).

## 3. 1926-1950: THE TECHNOLOGY OF COMMUNICATION

In the period between the two world wars, the concept of cognition was socialized. Cognition was still tied to knowledge and the process of knowing. However, the emphasis now came to lie in "knowing-in-relation-to-something-else." Educators, psychologists, sociologists, anthropologists, philosophers, and political thinkers emphasized the notion that cognition involves not only the attainment of knowledge but also action on the basis of that knowledge.

Numerous schools of thought converged to give impetus to the idea that cognition involves interaction with the environment. Anthropologists were calling attention to the effect of cultural differences on cognitive orientation and structure. Social psychologists, following the example of Hugo Münsterberg, undertook studies of the effect on an individual of group activities and judgments. With the translation into English, in 1936, of Karl Mannheim's *Ideology and Utopia*, the sociology of knowledge, which stressed the relationship between cognitive criteria and social positions, became another focus of attention. Philosophers were commenting on the interplay between language and thinking, noting that "we must distinguish between *thinking* truly and *speaking* truly. The former is an individual affair, the latter a social affair (Russell 1927, p. 260)." The role of language and social interaction in the development of cognitive processes and the acquisition of knowledge was emphasized further by the increasing attention paid to

the special problems of the deaf, dumb, and blind.

Meanwhile, among educators these dominant tendencies of thought were reflected in the progressive movement which stressed community interaction, functionality and integration of the curriculum, as well as guided student activity. Characteristic of an even more widespread attitude among educators was the content of a report by a Commission of the National Education Association on the Reorganization of Secondary Education that appeared in 1918. This widely circulated study, that exerted considerable influence during the years to come, set forth the following as the fundamental purposes of education: ". . . health, basic skills, home membership, vocations, citizenship, worthy use of leisure, and character (Wesley 1957, p. 76)."

Among the fields of study within psychology that developed during this period and were of particular influence in shaping subsequent work in the technological augmentation of cognition were behaviorism, physiological and animal psychology, industrial psychology, and developmental–child–psychology.

In 1925, more than a decade after he had begun publishing on the subject, J.B. Watson's book *Behaviorism* appeared. In it, the role of conditioning assumed a central place. Shifting from an earlier position, Watson, by 1925, "had espoused a radical environmentalism, and had discarded instincts and other forms of inherited tendencies. The remaining unit of native behavior was the reflex; the unit of habit was the conditioned reflex (Hilgard and Marquis 1940, p. 13)."

During the preceding decade there had been scattered experiments on human conditioning in the United States. Aside from Watson himself, the chief pioneer was Florence Mateer of Clark University who, influenced by the work of Pavlov, between 1914 and 1916 had experimented with child feeding and had found herself conditioning her subjects to undergo chewing and swallowing movements in response to having a bandage placed over their eyes. In the 1920's, experimental and theoretical conditioning studies increased, partly in response to the work of the American pioneers, partly in response to recent translations of earlier accounts by the three Russian physiologists, Pavlov, Bekhterev, and Sechenov. This spreading interest brought with it varying emphases as well as some departures from Watsonian views.

On a preponderantly theoretical level, C.L. Hull contributed greatly to the study of learning by developing explanatory schemes in which emphasis was placed on physiological and physical processes placed in a logico-mathematical framework. Hull, whose complex theory changed in some respects over the years, postulated "intervening variables" such as "drives" and "habits" as relating stimulus and responses. Basic to his notions on learning was the concept of reinforcement. In contrast to this stood the theory of "purposive behavior" that had been developed by Tolman (1932), who had studied with Münsterberg and Holt at Harvard. Although the concept of the "intervening variable" was due to him, Tolman rejected the idea of reinforcement as a prerequisite to learning. He postulated different types of learning; in particular, he called attention to a process he termed "latent" learning and exemplified it by the following experiment: Two groups of rats were placed in a maze. The first group was in the maze for several days, being fed regularly in the goal-box, and leisurely strolling through the maze during this period. Then food was removed for some time and the rats were placed at the starting point. They quickly found their way to the goal box. On the other hand, the second group, which had not had the experience of exploring the maze at leisure, had considerable difficulty in finding the shortest way to the goal box. Quite opposed to the notions of interposing extra variables between stimulus and response was E.R. Guthrie, who considered the temporal and spatial contiguity of stimulus and response as essential to learning. His work on the *Psychology of Learning* (1935) was widely read and frequently quoted by educators and psychologists alike.

The man whose name came to be most prominently associated with efforts at machine augmentation of cognition is B.F. Skinner. In the 1930's he began to discuss what he termed "operant conditioning." Instead of imposing a conditioning stimulus on the subject, Skinner let the subject spontaneously operate on its environment until it found a specific response which was then reinforced.

Under the impact of behaviorism, studies of animal behavior became common. However, such studies had been conducted since the turn of the century. Pavlov's dog and Köhler's apes had become world-famous by the 1920's. The dog became the classic example of conditioning; the apes supported the opposing suggestion of Gestalt psychology, according to which perception of relationships between objects is as basic as the response to a specific stimulus. Among American animals that were to become particularly famous in the study of cognition and learning were Thorndike's cats, Skinner's rats and pigeons, and a multitude of other rats that had been conditioned by behaviorists of varying persuasions.

In 1898 Thorndike completed his doctoral thesis in which his cat-problem box was first described: A cat was placed in a box, food was placed outside the box, but the cat was permitted to see the food through the slats of the box. By a method of "trial, error and accidental success (Thorndike 1898)," the cat found a mechanism in the box whereby it could open the box to get to the food. Over numerous repetitions of the experiment, the cat's activity changed from the random attempts that resulted in its accidentally tripping the proper latch, to a direct approach of the latch.

In the 1930's, B.F. Skinner developed a box for operant conditioning. It contained a lever and an automatic food dispenser so connected that pressing the lever released a food pellet which then dropped into a dish that was accessible to the animal. Among the experiments performed with the box were studies of the effect of intermittent reinforcement: After the animal had been conditioned to finding the food, the pellet was withheld for a number of times of pressings of the bar, after which it reappeared. Finding fairly high rates of

response, Skinner proceeded to long sequences of investigations with pigeons pecking at a key, to study the relationship between schedules of reinforcement and response rate. The pigeons maintained remarkably high response rates, continuing with 250 pecks for a ten-minute period during which the pellet was withheld.

The applicability of results of animal studies to the corresponding human situation has frequently been questioned. Although general analogies can be drawn, it is often difficult to reproduce a given experiment or situation. One of the chief arguments given against making such analogies is the more complex nature of the human nervous system. Also certain distinctions, of importance in studying animal behavior, become empirically meaningless when applied to humans. One such example is the differentiation between primary and secondary reinforcement. In the 1930's, groups of chimpanzees were trained to use poker chips in a vending machine in order to get food, as well as to accumulate such chips for food of higher value. These widely cited experiments were taken to show that the chips had acquired secondary reinforcement value. However, they led to no conclusive non-trivial results concerning humans; the chief reason for this is the difficulty in distinguishing basic human "drives," leading to the pessimistic view that "for the student of human learning the distinction between primary and secondary reinforcement seems doomed to failure (Annett 1969, p. 34)."

In other cases, it has been easier to undertake analogous, even comparative, studies of animals and humans. For example, in the period under consideration, there was considerable discussion of the implications of the "delayed response experiment," devised by W.S. Hunter of Chicago and Kansas. Hunter, in several articles, of which the first was published in 1913, reported on studies undertaken with rats, dogs, raccoons, and children: The subject had the task of finding food or a toy that was hidden in one of three possible locations. The proper location was indicated by a signal such as a lighted bulb. First the subject learned to respond to the signal; then delays were introduced by removing the signal. The children did considerably better in the experiment than the rats and raccoons. Later, investigators did similar experiments with children and animals in which, however, particular attention was paid to differences in their responses as, for example, to color cues (Woodworth 1954, pp. 604-608).

Of the growing amount of relevant work done in physiology during the years in question, the following are characteristic examples: In the 1920's and 1930's there was considerable research in localized brain functions. For instance, S.I. Franz investigated the effect on learning of operating on specific portions of the brain. Lashley drew the important conclusion that control of certain functions usually localized in a given neurocenter can be taken over by another portion of the brain if that center has been destroyed. In the 1930's and 1940's there was a general upswing in neurosurgery, coupled with studies of its effect on behavior.

Dynamic models, such as that presented in Hebb's *The Organization of Behavior* which appeared in 1949, led to thinking of the brain as a system of interlinked circuits; occasional recoupling of such circuits could be conceived of as an explanation for effects such as the above-mentioned one studied by Lashley. Beginning in the late 1940's, there was a great deal of research involving chemical and electrical stimulation of certain brain areas. However, the increasing importance of this work can be attributed to the context in which it has been done rather than to its novelty. Indeed, Hugo Münsterberg had already studied the effect of drugs on problem-solving, and interest in electroencephalographic studies had been maintained at least since 1929, when the "alpha rhythm" was described by Berger in Germany.

The field of industrial psychology is of importance in the present context, because of the impetus it gave to the development of training techniques and devices. In the early 1920's, private industry as well as the U.S. Government began to hire psychologists for personnel selections, testing, efficiency studies, and training programs. Among the studies of particular interest were experiments that brought further evidence concerning the effect of knowledge of results in reducing fatigue (Annett 1969, p. 112). One of the results that has come to be of interest in relation to applications of technological training devices is that attained in the 1940's by Lindahl, who taught proper foot control on a lathe by having the trainee watch a kymograph recording good and poor control patterns (Annett 1969, p. 45).

By the 1920's, the earlier, occasionally haphazard, attempts at child study had been turned into a systematic field of psychological investigation. Arnold Gesell studied children up to the age of five years; M.M. Shirley concentrated on the first two years; Anna Freud and Melanie Klein concentrated on adjustment problems and disturbed children; various private schools experimented with new techniques of educational psychology. However, the work that had perhaps the most profound impact on subsequent studies in cognition was that being done in Switzerland by Jean Piaget.

Piaget began his studies in the 1920's. His initial results were based on verbal encounters, an approach which he rejected subsequently. In the 1930's he engaged in a detailed developmental study of his own children, beginning before they had reached the stage of verbal communication. He developed a theory postulating four stages of development: That of sensorimotor intelligence, beginning at birth and lasting up to the age of eighteen to twenty-four months; that of "pre-operational" growth, in the first phase of which—between the ages of two and four—the child is developing up to the point of identifying classes of objects, whereas it develops intuitive thought during the second phase, between the ages of four and seven; that, from seven to eleven, in which the child performs concrete logical operations, learning to deal with classes, relations, and numbers; and, finally, that between the ages of eleven and fifteen, when the stage of formal operations is reached, in which abstract thought is developed.

Piaget distinguished between perceptual and cognitive processes: Perceptual processes are essentially probabilistic and irreversible; cognitive processes are reversible. It is the reversibility that is attained through the stages of growth just outlined. Piaget noted that this development "corresponds, no doubt, to certain laws of structuration of the nervous system which it would be interesting to try to formulate in regard to qualitative mathematical structures (groups, lattices, etc.)" (Piaget 1952, p. 256). It is this last task to which Piaget devoted himself after World War II.

In contrast to other "child psychologists," Piaget's aim at the outset was a more general one than the study of children. After three decades of work primarily devoted to such study, he returned to his original aim: "My own idea . . . has been that intellectual operations proceed in terms of structures-of-the-whole. These structures denote the kind of equilibrium toward which evolution in its entirety is striving; at once organic, psychological and social, their roots reach down as far as biological morphogenesis itself" (Piaget 1952, p. 256).

To consider factors contributing to the technological augmentation of cognition in this period, it will be of interest to look at selected devices associated with the psychologist's laboratory, the school and home, the college classroom, and the military camp respectively: the maze; the radio, the motion picture and other audio-visual aids; the teaching machine; and military training devices.

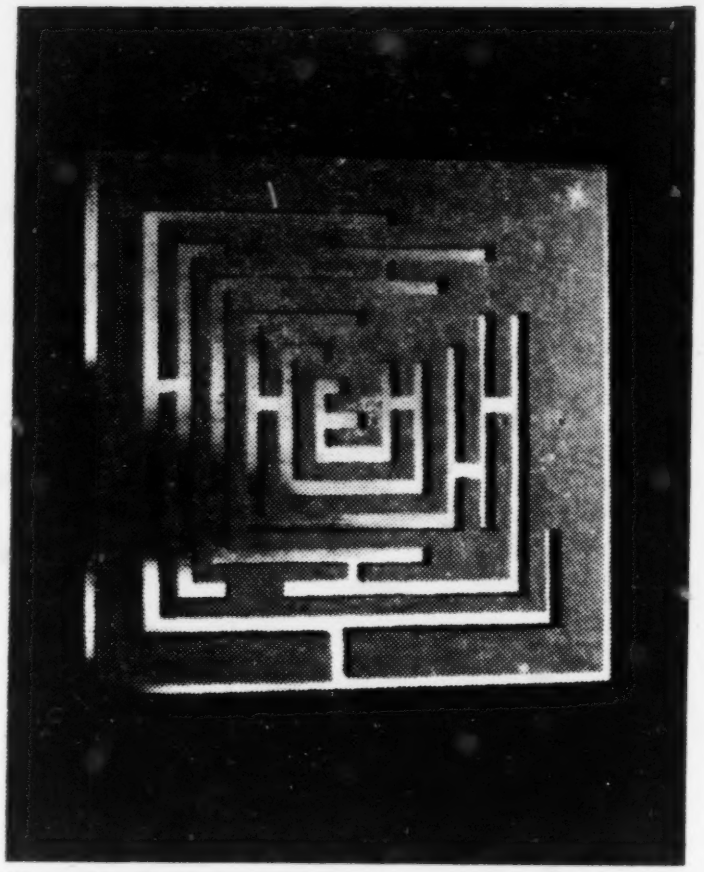


**Figure 48.** Finger maze; raised wooden alleys. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photograph courtesy of Archives of the History of American Psychology.*

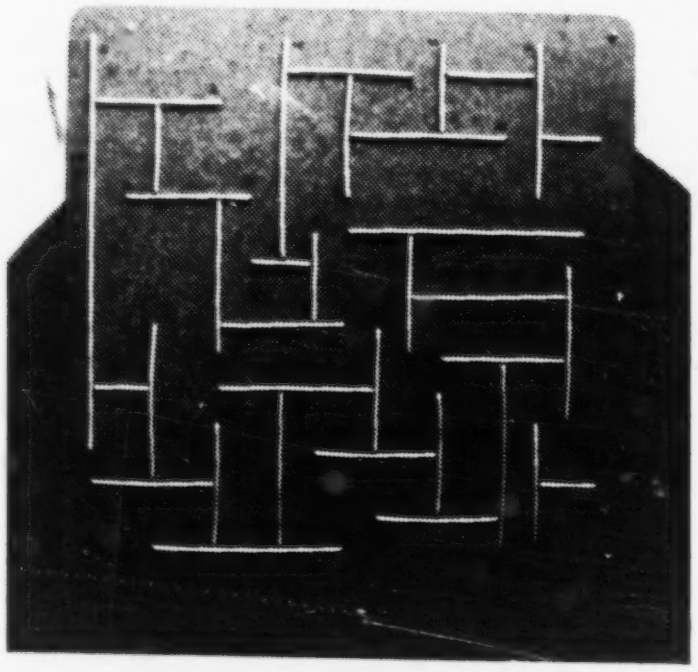


**Figure 47.** Finger maze; staples on fiber board. Used at the Ohio State University. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photograph courtesy of Archives of the History of American Psychology.*

## THE MAZE

In the 1920's the maze came to be perhaps the most widely used device for psychological studies of learning. Systematic maze studies in psychology had been begun just before the turn of the century when W.S. Small built a wire-mesh maze, using the plan of the famous Hampton Court maze. Two white rats placed in the maze learned their way to the food-containing goal within a day. During the first decade of the century, Small as well as J. B. Watson performed studies designed to discover what senses were used in learning the maze; Watson, by a process of elimination, concluded that it was the kinesthetic sense. Watson's conclusion was challenged in the 1920's when several investigators showed that rats deprived of the kinesthetic sense after they had learned a maze could still find their way easily, and that animals could learn a maze after the elimination of kinesthesis as well. These studies led to the conclusion that a multiplicity of senses is involved.

Human-maze studies initially presented a space problem, because in early studies, children and adults actually walked through the maze; existing outdoor mazes in amusement parks were used, as well as specially constructed outdoor mazes. About 1914, a small maze was developed to be used by a blindfolded subject who followed a slot path cut through a board by using a pencil or stylus. A record of the path traced and the errors made is left by the pencil or stylus on a paper placed underneath the board, or noted by an observer.

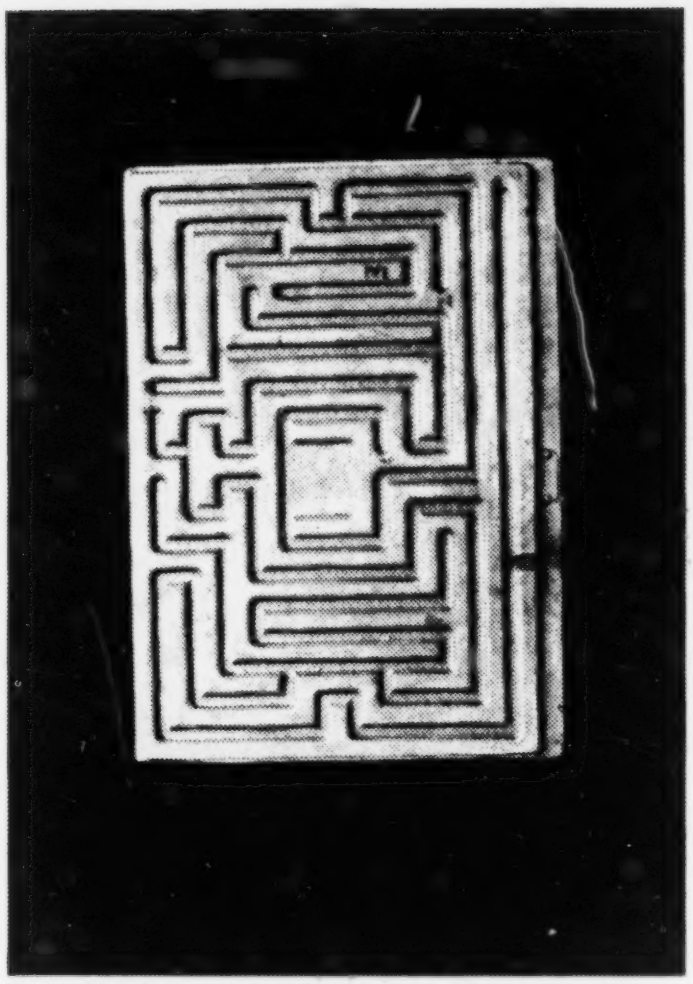


**Figure 49.** Finger maze; metal. Used at Denison University. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photograph courtesy of Archives of the History of American Psychology.*

Following earlier examples, in about 1927 Miles developed an elevated finger-maze that, in various forms, came to be widely used. Here, the alleys determining the maze pattern are superimposed on the board so that the blindfolded subject can follow the paths directly with his fingers. The alleys could be made of staples (Fig. 47), string, wood (Fig. 48), or metal (Fig. 49). Another version of the Miles maze was a two-story duplicate maze, used for motor coordination studies. The lower maze, with the same pattern as the upper, was mounted on a rotating platform so that it could be set at any angle with respect to the upper. The subject traced the lower maze with one hand, the upper with the other; he could not see the lower, but was allowed to see the upper maze while tracing (Stoelting 1936, p. 150).

Other visible mazes were developed in the 1920's. Carr in 1921 described a stylus-operated slot maze, the general pattern of which was visible to the subject; however, there were built-in stops at the bottom of the slots that could not be seen. Variations, including electrical models, of this type of maze were popular in the 1930's and 1940's. Electric components were used also for special features such as automatic recording of the path, or–especially in animal mazes–administering a shock. In other forms of visible table mazes the subject was allowed to see only a small section of the maze at a time, approximating the amount he would see if he were walking through a large alley maze.

Fully visible mazes were used as well, particularly by Porteus, developer of the wide-spread paper and pencil maze tests named after him; Porteus, encouraging the subject to view the overall maze before starting, used this feature to test planning and sustained attention (Woodworth 1954, pp. 646-651). Various "gimmicks" were frequently introduced in these different forms of mazes. Thus, in one slot maze, designed for use with children between the ages of four to nine years, a toy shoe was used instead of a stylus. It was attached, so that it could be moved along the maze but could not be taken out. A toy clown served as goal, and the child was told to bring the shoe to the clown. The maze was advertised as testing "resourcefulness, foresight, persistence, poise, mental control, and stability (Stoelting 1936, p. 126)."

Just what could be learned about learning from these devices, still widely used, among other things depended on the style and pattern of the maze, the type of subject, and the controls established by the experimenter. The following are a few examples of experiments with mazes, the results of which have been discussed in relation to basic design of teaching machines.

In the 1920's and 1930's, there was considerable interest in the effect of guidance on learning. Experiments pertaining to guidance in maze learning had been conducted by Ludgate in 1923, when he manually guided a human subject's hand through a maze. Shortly thereafter Koch reported on guidance studies involving animals as well as humans. Aside from the observation that guidance appeared slightly less effective with humans than with rats, these studies were of interest primarily with regard to questions concerning the timing and the amount of guidance given. Subsequent investigators, notably a group at Chicago working with Carr, paid particular attention to the problem of "over-guiding." Their general conclusion was that it was best to provide a small amount of guidance during the early stages of a trial sequence. In a report issued at approximately the same time, R.H. Waters differed from these conclusions on the basis of tests done in human-maze guidance; he was chiefly opposed to putting an upper limit to the number of guided trials (Annett 1969, pp. 79-83, 153-159).

Another group of tests performed in maze-learning experiments dealt with the effect of rewards and punishments. Tests administered in the mid-1920's appeared to indicate that animals subjected to electric shock after errors decreased their time and error rate. In the early 1930's, Tolman and his associates determined that administering either a shock or ringing a bell after a correct response was more effective than doing the same thing after an error had been committed. This, and subsequent experiments conducted by other investigators, led Tolman to suggest replacing Thorndike's law of effect by a law of emphasis (Annett 1969, pp. 82-83).

## RADIO AND AUDIO-VISUAL AIDS

In the late 1920's, interest in utilizing radio for educational purposes had increased sufficiently to induce consideration of national network broadcasts. In 1928 the National Broadcasting Company first broadcast a nation-wide program in music appreciation that continued until 1942. Organized by Walter Damrosch, the broadcasts were divided into four dozen half-hour lessons for four sets of grades, ranging from elementary school through high school. Teachers could obtain a manual which contained the broadcast schedule for the school year and what was essentially a lesson plan, together with guides to available recordings of the selections on the programs. The programs were designed to be listened to in conjunction with the use of this preparatory material.

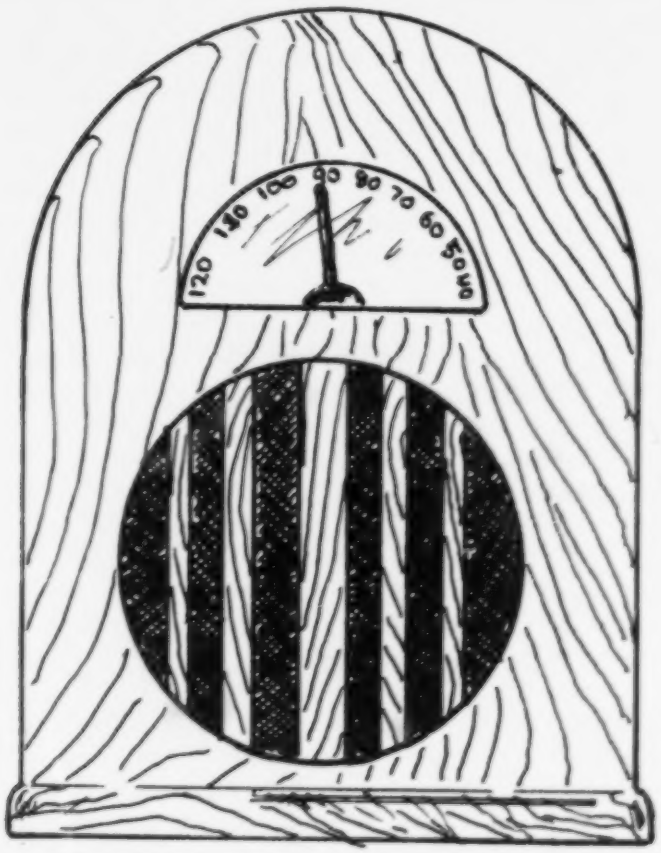



**Figure 50.** Radio.

In 1930, the Columbia Broadcasting System initiated a nation-wide educational series which lasted for a decade. It concentrated on a variety of school subjects. However, according to Gilbert Seldes (Saettler 1968, p. 200), it had a more difficult time than the NBC music program, apparently because it broke up the morning sequence of soap operas. Other educational programs on the two networks were produced in the 1930's under sponsorship of the U.S. Bureau of Education.

Meanwhile educational radio stations, first established in the early 1920's, continued to function even though the programs were rather unexciting, and consisted largely of recorded standard course lectures; the situation

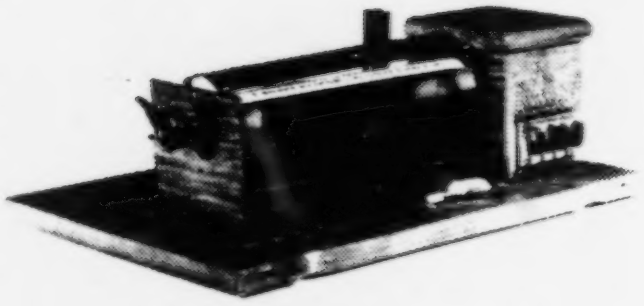


**Figure 51.** Pressey teaching machine (1925). *National Museum of History and Technology. Photograph courtesy of the Smithsonian Institution.*

barely improved with the spread of educational stations to the FM band after 1938.

In the schools, occasional use of radio was complemented by increasing use of the phonograph. In addition, the audio-visual instruction movement grew in scope, content, and organization. Courses in teacher training for aduio-visual instruction not only increased in number but became mandatory in some States; serial publications on the subject flourished; university extension divisions and major city school systems served as distributors; and numerous textbooks, manuals and film catalogs became available to teachers. Besides the use of moving and still films, audio-visual instruction included field trips, which covered industrial plants, museums, concerts, theaters, farms, and other urban and rural phenomena deemed to have educational value.

Occasionally special features were developed, such as language instruction phonograph recordings that were timed to allow for student response, or films that permitted similar interruptions for practice, response or discussion. However, frequently the films or phonographs were standard productions, falling into the same general categories of advertisement and entertainment as those described for the earlier period.

## TEACHING MACHINES

In 1924, Professor Sidney L. Pressey of the Ohio State University first presented before the December meeting of the American Psychological Association a mechanical device described as a testing and test-scoring machine which also taught. An improved version of the machine was again presented the following year and described in a publication in 1926 (Pressey 1926). The inventor of the machine has come to be known as the "father of the modern teaching machine."

Pressey's improved first device (Fig. 51) contained a platen (roller) such as that found on a typewriter. On this a roll of paper could be attached; a cover over the platen and the roll had a horizontal slit exposing one or two lines at a time of the material typed on the paper roll. The paper contained a set of multiple-choice questions; there were up to four numbered choices for each

question. To the right of the platen was a keyboard containing four keys. The student pressed the key corresponding to the number of the answer he chose. A counter at the back recorded the number of correct responses. When the machine was in the "test" mode, pressing the key activated a mechanism turning the platen so that the next question appeared; however, a lever at the back could be set which changed the mechanism to a "teach" mode; when the machine was in this mode, the mechanism governing the rotation of the platen was activated only after a correct response had been given. As long as the student gave the wrong answer, he was thus forced to stay with the question. The counter still remained in operation, counting all attempts. As Pressey noted, the machine could also be used with true-false tests, by simply using two keys.

In discussing his machine, Pressey pointed out that it tied in with some of the basic laws of learning that were then in vogue as discussion topics among educators and educational psychologists:

> The "law of recency" operates to establish the correct answer in the mind of the subject, since it is always the *last* answer which is the right one. The "law of frequency" also cooperates; by chance, the right response tends to be made most often, since it is the *only* response by which the subject can go on to the next question. Further, with the addition of a simple attachment, the apparatus will present the subject with a piece of candy or other reward upon his making any given score for which the experimenter may have set the device; that is, the "law of effect" also can be made, automatically, to aid in the establishing of the right answer (Pressey 1926, p. 374).

Although demonstration of the machine met with polite interest, it did not create a great deal of excitement. Nevertheless, Pressey stayed with the concept, trying it out in his classes at Ohio State.

In 1927, Pressey published the description of a new machine (Fig. 52). This was very similar to the first device, but had the additional feature that after a

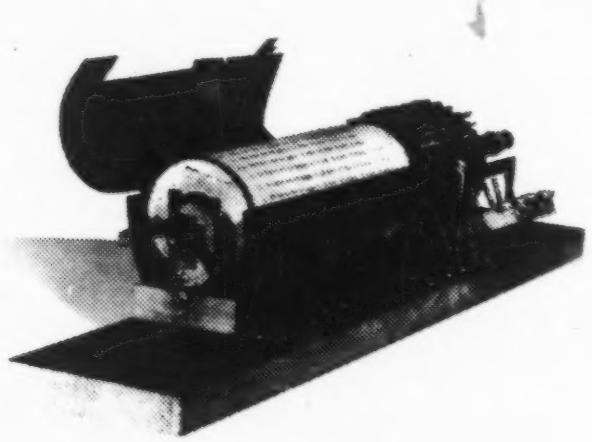


**Figure 52.** Second Pressey teaching machine. *Photograph courtesy of the Smithsonian Institution*

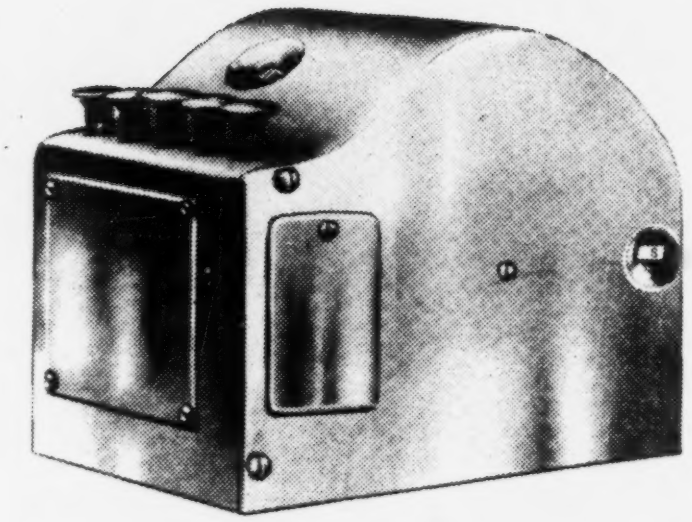


**Figure 53.** Pressey teaching machine, by the W. M. Welch Scientific Company. *Archives of the History of American Psychology, University of Akron, Akron, Ohio. Photograph courtesy of the Smithsonian Institution.*

sequence of questions had been completed—implying that every question in it had been answered correctly, though not necessarily on the first attempt—the sequence was repeated. After the sequence had been completed a given number of times, questions were eliminated to which the correct answer had been given at the first try in each sequence. The number of times the questions had to be answered correctly, in succession, could be adjusted. Of course, once every question was answered correctly the required number of times the machine stopped; at this point it issued a little coupon. Thus, in addition to retaining the features of the earlier machine, this device was designed to avoid overlearning.

In the 1927 paper describing his second machine, Pressey also called attention to possible disadvantages of the machine, which were being studied by his graduate students. One was the possibility of establishing wrong associations by repeatedly presenting wrong answers among the multiple choices; another was the possibility of establishing a transfer problem as the result of unknown distinguishing characteristics of key-pressing reactions.

To arouse interest in this field, Pressey, in the same paper, suggested possibilities for other types of teaching machines. In particular, he mentioned the idea of building a machine for teaching arithmetic, which would have an adding machine keyboard and have problems presented either on a punched paper tape or a punch card.

A commercial version (Fig. 53) of Pressey's machine was put on the market in 1929 by the W.M. Welch Scientific Company. It had a capacity for 100 questions: In addition to discussing the features of the machine noted above, the advertisement for it stressed that it eliminated grading of papers and making errors in grading. However, after the sale of about 100 machines, the Welch Company took the machine off the market in 1934. The interrelated reasons for this were apparently the low number of sales, the need for design improvements, and the Depression.

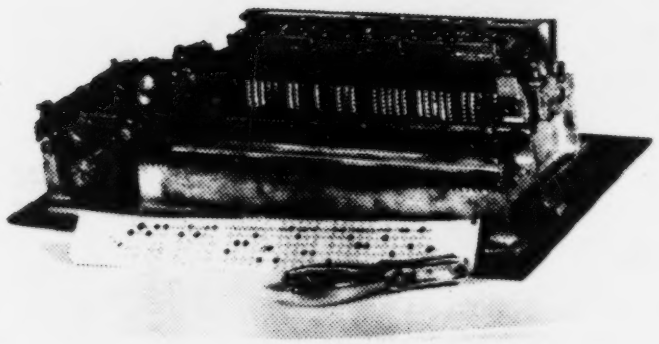


**Figure 54.** Pressey test scoring and tabulating machine. *Photograph courtesy of the Smithsonian Institution.*

Meanwhile, in 1932, Pressey reported the construction of yet another device (Fig. 54). This machine, using a punching method, was designed to tabulate test results by item, and to score and total the results. The student punched his answers on a strip of paper designed for that purpose; the strip was then placed on a scoring plate. This scoring plate contained a set of holes corresponding to the punch locations on the strip. The examiner placed pins into the holes corresponding to the correct answers. These pins were held up by spring pressure so light that if the punch location over the pin was blocked, it was kept down by the strip. To score the test, a carriage was run along the strip; this had a ratchet wheel engaging the pins that were sticking up so that they rotated a counter on the carriage. This resulted in the totaling of all correct answers. The item counting was handled by simply having individual counters for each question, that is, for each row of the strip.

Although none of these early devices were a commercial success, they were not forgotten completely. One important aspect of Pressey's work of this period was that he kept interest in the development of teaching devices alive among his students. Some of the work of his graduate students consisted of analyzing the use of machines. Thus, a study was made of the use in undergraduate teaching of the teaching machine as well as of the use of the item-tabulating scoring device (Little 1934). Others proceeded to develop new devices of their own. For example, J.C. and H.J. Peterson developed a "chemocard" that changed color at the spot where an answer had been marked, thus giving an immediate knowledge of the result and providing a simple aid to totaling the scores. The device was used as a learning aid with encouraging results (Peterson 1931). The Petersons also developed a "punchboard" technique, essentially similar to the preceding process, but utilizing punched holes instead of colored spots. All of these were basically variations on the concept of having, in Pressey's terminology, a "generalized answer unit (Pressey 1932)."

## MILITARY TRAINING DEVICES

World War II provided considerable impetus to developments in the technology and technique of training. The needs of the military served, in part, to implement the development of existing objects and methods; in part, they led to new devices.

Among the objects that received fresh attention during the 1940's were some of the devices developed by Pressey and his students. Under sponsorship of the Special Devices Center of the Office of Naval Research, studies on the punchboard (Fig. 55) and the chemocard were conducted even after the end of the war (Jensen 1949; Pressey 1950); these laid the basis for further studies by graduate students in the 1950's (Stephens 1953; Jones 1954; Severin 1955). A "drum tutor" was built, which was essentially a sturdier form of the early Pressey teaching machine, similar in the compactness of appearance to the commercial version (Fig. 56). It

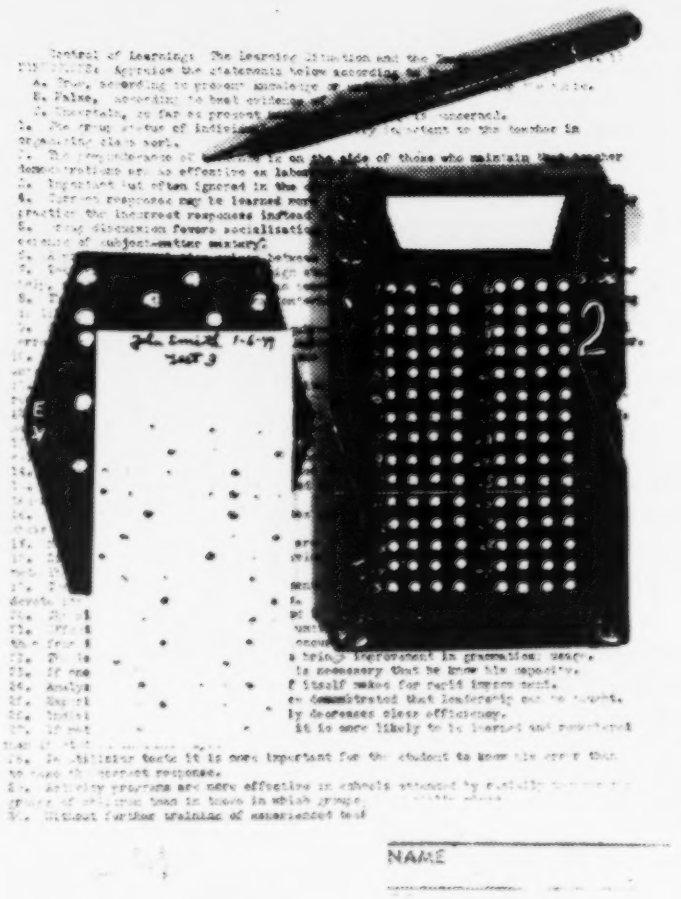



**Figure 55.** Pressey punch board. *Photograph courtesy of the Smithsonian Institution.*

received its name from the fact that the questions were placed on a drum inside the casing; clearly, the principle was that of the first machine, in which a roller had been used. There were a few special features, including a bell that rang when the machine was opened, thus alerting those present to potential cheating attempts.

Another device that had been invented years before the outbreak of war, but became world-famous through

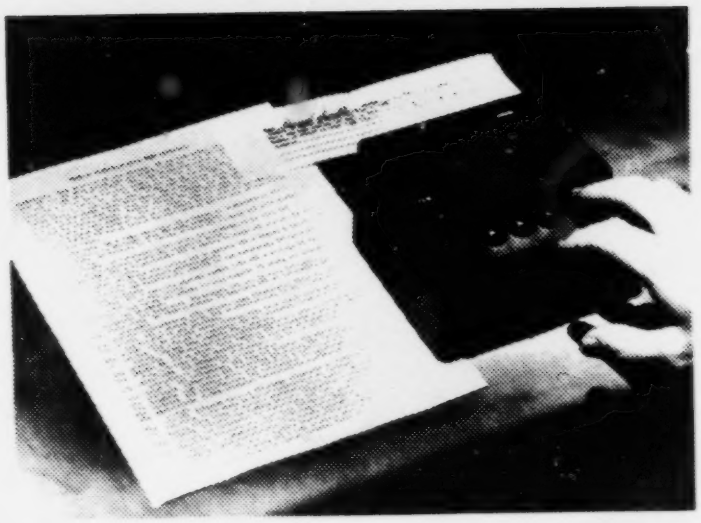


**Figure 56.** Pressey drum tutor. *Photograph courtesy of the Smithsonian Institution.*

its use by the military, was the Link trainer (Fig. 57). This effective training device for pilots gave impetus to broadly-based studies in simulation techniques during the post-war period.

The special services of psychologists were called upon in World War II, as they had been in World War I. This time, an Applied Psychology Panel was established as part of the activities of the National Defense Research Committee (Bray 1948). Among other things, this group was responsible for a considerable amount of research on new training devices. The following examples are intended to illustrate briefly some of the areas of their concern. It will be noted that the devices varied

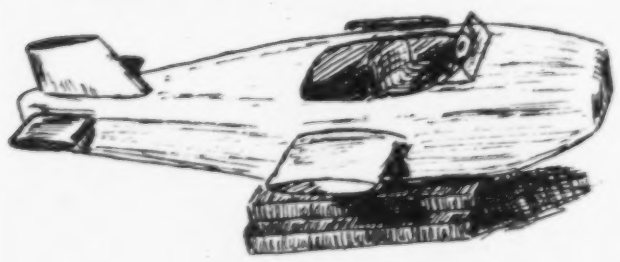


**Figure 57.** Link trainer.

greatly in acceptability, usefulness, and technological sophistication.

One of the problems that was studied in great detail was that of night vision. In conjunction with work on the factors in night vision, on testing night vision, and on training for improved night vision, the device pictured in Figure 58 was developed. A wooden box designed to be used in semidarkness was arranged to hold a curved plastic plate on which a set of figures was printed. Behind these interchangeable plates was a fixed plate, coated with radium salt, that provided illumination. In front of the plates was an inlet against which the subject placed his eye. The figures on the cards served specific purposes (Fig. 59). Thus, a house with various small

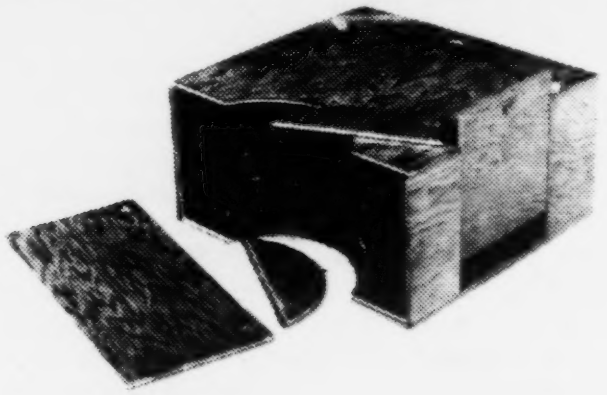


**Figure 58.** Training device for night lookout. From Bray 1948 (Plate I). *Photograph courtesy of the Smithsonian Institution.*

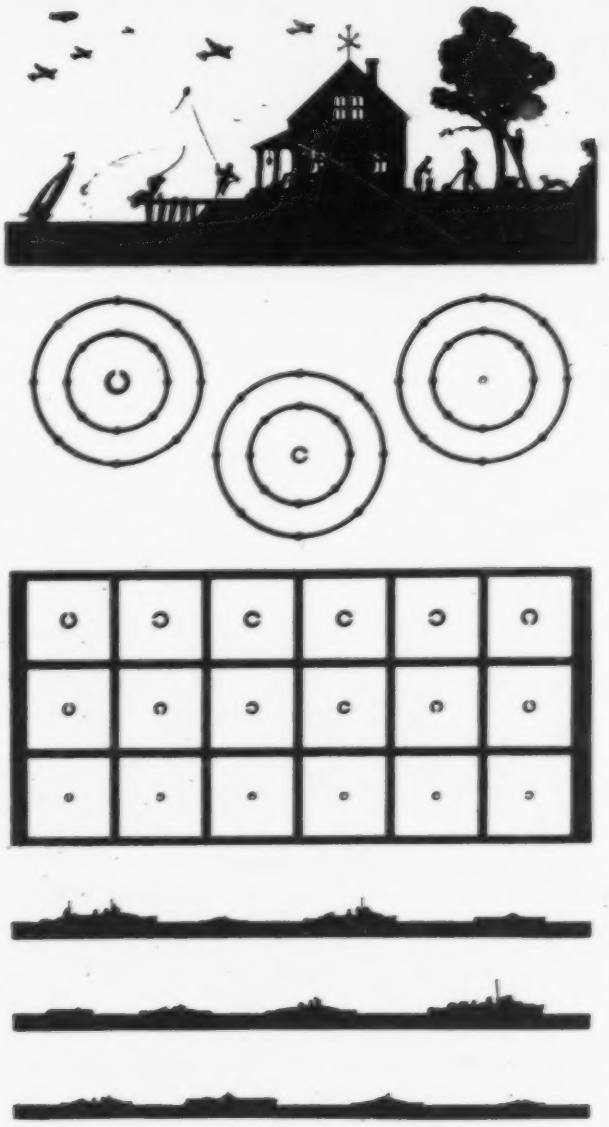
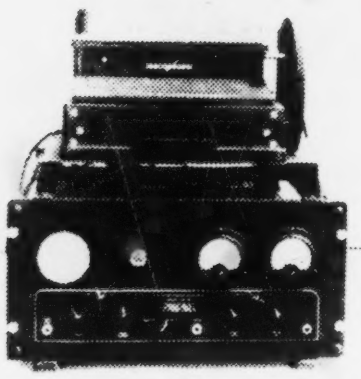


**Figure 59.** Interchangeable stimulus cards, for the night lookout trainer. From Bray 1948 (Plate II). *Photograph courtesy of the Smithsonian Institution.*

figures around it was used to test increasing adaptation to the dark, since the smaller figures are seen in the course of that adaptation. Representative ship silhouettes were used to train night lookouts in identifying different types of ships. This simple device, designed to serve as a Night Lookout Trainer, was recommended for widespread use (Bray 1948, p. 114), but apparently did not find much actual application in the Navy.

In contrast to this, a communications trainer built for the Bureau of Ships gained wide-spread attention. This was the "Morse-Code Actuated Printer"; it consisted of an electric typewriter, with appropriate circuitry attached, that translated an input of radio code signals into ordinary language (Fig. 60). It functioned as a training device because it called attention to errors made by the person transmitting the code signal. If a letter in a word was miscoded, this would obviously result in the wrong symbol being printed out. The trainee could thus obtain immediate knowledge of his results; in addition, the precise nature of the error made could be determined from the print-out. For example, suppose the trainee intended to transmit the word "communications"; if the typewriter typed out "commanications" it was clear that he had skipped a dot in the letter "u" (..-), changing it to an "a" (.-). If the typewriter typed out "communications" it indicated that he had inserted an extra dot ("v"=...-). If the word came out as "commitnications" it meant that he had paused too long in sending the letter "u", thus, splitting it ("i"=.. and "t"= -).

Among other innovations of the period were voice communications training installations (Fig. 61) intro-



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THAT JAPAN IN NAME HIROHITO READY ACCEPT TERMS

ALLIED POTSDAM SURRENDER DECLARATION . BROADCAST

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WITHOUT COMPLETING WHAT PURPORTEDLY WAS

OFFICIAL ANNOUNCEMENT . TWO HOURS LATER

TOKYO STILL NOT RESUMED AIR .

**Figure 60.** Morse code actuated printer. From Bray 1948 (Plate III). *Photograph courtesy of the Smithsonian Institution.*

**Figure 61.** Voice communications training. From Bray 1948 (Plate IV). *Photograph courtesy of the Smithsonian Institution.*

duced for the Army Air Forces; these centers, somewhat reminiscent in appearance to collegiate foreign language training laboratories of the following decade, provided training in effective techniques of transmitting pilot messages. This included study of the choice and use of appropriate radios, microphones, and headsets involving exercises in loudness, pitch, and articulation, as well as rate of speech and choice of words. Much of the related research came from the Psycho-Acoustic Laboratory at Harvard University.

In addition to the preceding, numerous important ordnance trainers were developed. Much of this work–for example, that concerned with tracking training–in the 1950's led to generalized studies of the skills involved (Wolfle 1951; Bilodeau 1966).

## 4. 1951-1970: THE TECHNOLOGY OF MACHINES

In the 1950's and 1960's several new approaches began to affect the concept of cognition. On the surface, definitions applied to cognition did not appear novel. Thus one could find cognition defined as "a general term covering all the various modes of knowing–perceiving, remembering, imagining, conceiving, judging, reasoning (Drever 1952)," or as "a generic term for any process whereby an organism becomes aware or obtains knowledge of an object (English and English 1958)." Psychologists discussing cognition quoted a statement from the *Handbook of Social Psychology:* "Cognitive theory might be expected to deal with the problem of how man gains information and understanding of the world about him, and how he acts in and upon his environment on the basis of such cognitions (Colorado 1955)."

All three statements appear to represent rather traditional views. The last one seems simply to reflect the attitude of viewing cognition with regard to the environment that had become prevalent since the 1920's. However, the use of the term "information" provides the clue to more recent influences.

In 1949, Shannon and Weaver published *The Mathematical Theory of Communication,* a work that brought attention to Shannon's earlier contributions to the field of information theory. In particular, psychologists began to use the theory and developed new experiments under its influence (Brown 1966). The implications of applying information theory to psychology were not always understood. For example, there was misinterpretation of the term "information." Thus, it has been noted (Pierce 1961, p. 24) that "*information* is sometimes associated with the idea of *knowledge* through its popular use rather than with *uncertainty* and the resolution of uncertainty, as it is in communication theory." This is the point which makes the application of information theory to cognition of special interest.

Emphasis on probabilistic aspects of cognition was strengthened in the mid-fifties with the publication by Bush and Mosteller (1955) of their *Stochastic Models for Learning.* This supported the approach that considers learning as a sampling process.

Meanwhile, the earlier work of W. S. McCulloch and W. Pitts (1943) on the application of mathematical logic to the study of the structure of the nervous system was beginning to receive some attention, together with McCulloch's more recent work. Under the influence of Norbert Wiener (1948; 1956; 1961), the work of other researchers in the simulation of behavior and the general application of feedback became more widely known. By 1960, there was a full-length book on *The Structural Basis of Behavior* (Deutsch 1960), which has been called the "earliest application of 'cybernetics' (the study of self-regulating mechanical systems) to psychology (Thomson 1968, p. 409)."

These various theoretical approaches were closely related to the forceful technological developments of the period. Of particularly obvious influence were advances in electronics, especially the rise of the computer. The result of this convergence was that "technological augmentation of cognition" became associated with the use of feedback devices in the form of teaching machines and computers. An associated area of interest was the utilization of television.

### TELEVISION

The effect of television on cognition continues to be a widely debated subject. It will be practical here simply to review briefly some aspects of the development of "educational" television.

In 1952, the Federal Communications Commission concluded a period of prolonged discussion by reserving almost 250 television channels for specific educational use. Most of these channels were, and are, in the UHF range. Licensees were either educational institutions, non-profit educational organizations, or State or municipal educational agencies (Saettler 1968).

In addition to having educational programs on special channels, there have been similar programs on the regular commercial stations. It became customary to run college level lectures in a series with assigned reading, providing the equivalent of a regular college course. These have usually been scheduled for early morning broadcasts.

In the mid-fifties, closed-circuit television was introduced at a number of schools and colleges. This varied from programs that originated in a classroom to others that presented lectures from an office or studio to yet others that included experimentation with response from the listeners.

As had been true of the earlier efforts with radio, many of the educational programs on television tended to transmit a standard lecture, discussion, play, or concert via the screen without succeeding in utilizing or adapting to the special features of the medium. When a program on educational television broke away from the rather standard pattern, it was usually noted. The recent popularity of programs such as "Sesame Street"

**Figure 62.** Sesame Street, derived from National Educational Television.

(Fig. 62) seems to illustrate this. However, even in such programs, there are still difficulties in the attempt to transmit basic knowledge, skills, and moral virtues within the framework of a physical environment that appears to be set apart from the environment of viewer and producer.

## TEACHING MACHINES

In the title of a paper describing some of his machines in 1932, Pressey referred to these as "contribution[s] to the coming 'industrial revolution' in education." Although approximately a generation had passed before its arrival, the 1950's witnessed such a revolution. It is commonly associated with the attention created by B.F. Skinner in reporting on the application of operant-conditioning techniques to human learning, utilizing simple teaching machines.

In 1954, Skinner published a paper in which he called attention to the possibility of transferring to the classroom the conditioning techniques of the laboratory, whereby two pigeons had been taught to play a form of ping-pong. Calling attention to the lack of proper reinforcements in the schools, Skinner, among other things, stressed that the teacher requires the assistance of mechanical devices to act as reinforcing agents. He gave examples of devices that had been developed for this purpose.

The prototype machine that Skinner described (Fig. 63) consisted of a box containing a paper tape on which questions were printed. These could be seen, one at a time, through a window on top of the box. The student set the answer to a question by moving certain slides, containing digits in the case of an arithmetic machine, letters in the case of a spelling or reading machine. Correct answers enabled the student to turn a knob allowing him to proceed to the next question; giving a wrong answer caused the knob to be blocked (Skinner 1954).

In 1958, after some years of rather intensive experimentation, Skinner published an article in *Science* on teaching machines that reached a wide audience and provided the direct impetus for numerous experimental projects. The machines that Skinner had developed in the meantime were somewhat more sophisticated than the earlier boxes. Sets of "frames" stored on cards, tapes, and disks presented the problems to which the student responded. The principle of the machines was the same as that of the earlier one: If the student gave a correct response, he could proceed to the next frame; if not, the frame was held in position until he gave the correct answer. The feature of having a second sequence of the questions on a given disk that repeated only those which had been missed the first time was included as well.

Skinner stressed two requirements for a teaching machine: First, that the student compose his answer rather than selecting it from multiple-choice or true-false possibilities; secondly, that the student move through a sequence of steps. "Each step must be so small that it can always be taken, yet in taking it the student moves somewhat closer to fully competent behavior (Skinner 1958)." This approach, which was followed by the majority of teaching machine designers, is in contrast not only to the method of Pressey, but also to techniques advocated by others. Frequently cited among these has been Norman A. Crowder, who proposed a method of so-called "intrinsic programing." Crowder stressed that the student's knowing of results was not to be the primary aim of the machine; rather, he emphasized the importance of having the machine adapt its response to that of the student.

Crowder's idea of intrinsic or branched programming, became familiar largely through its appearance in the use of "scrambled" textbooks, in which different ques-

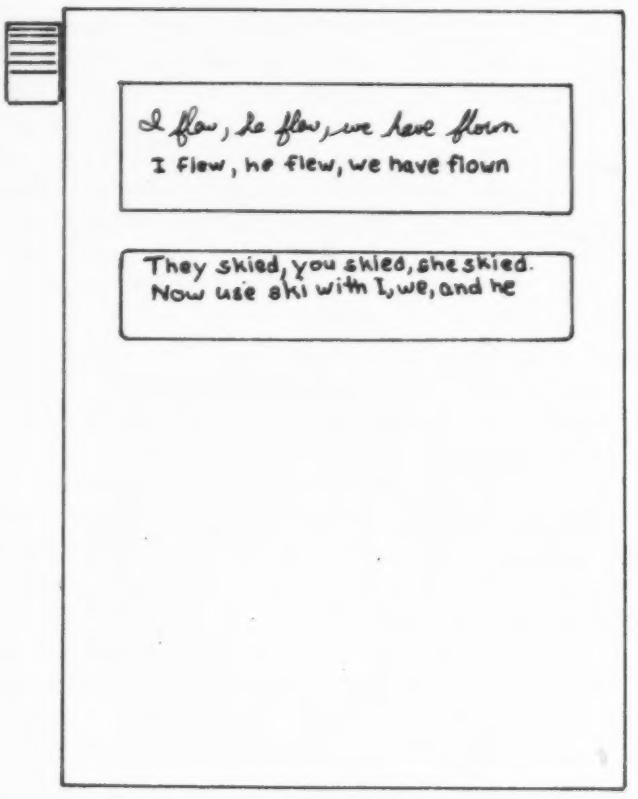



**Figure 63.** Skinner programmed teaching device.

tion sequences are pursued, depending on the responses given.

Although the designers of most small-scale machines followed the technologically simpler form of Skinner's machines, a few branched programming machines were built as well. One example, described by Crowder (Fig. 64) made the required scrambling feature possible by the use of microfilm. This machine, the Tutor, had a capacity of 10,000 images. The questions had choices that were assigned numbers which the student entered on a keyboard. Depending on the answer he had chosen, the next question then appeared.

While the debate over the merits of these and other approaches to teaching machine programming has continued (Part III), the alternatives have been made more easily available, and the branched programming method consequently has become more appealing, through the accessibility of large-capacity automatic computers.

Although during the late fifties a multitude of teaching machines, varying in name and shape more than in underlying principles, was manufactured (Foltz 1961), most of these quickly disappeared from view. This was due largely to the advent of computer-assisted instruction about 1960.

## COMPUTER-ASSISTED INSTRUCTION (CAI)

Aside from accounts of various experiments for the benefit of computer engineers and programmers, one of the first published reports concerning the use of a computer as a teaching machine appeared in 1959 (Rath, Anderson, and Brainerd 1959). An IBM 650 computer with typewriter input and output had been used to teach binary arithmetic. The program involved letting the student know his results, stopping when errors were made, and correcting wrong answers. There was also a possibility of skipping problems. The experience appeared promising, particularly because it coincided with the growth in availability of higher computer programming languages and computer peripheral equipment such as television-like display screens, audiophones, light pens, and the like.

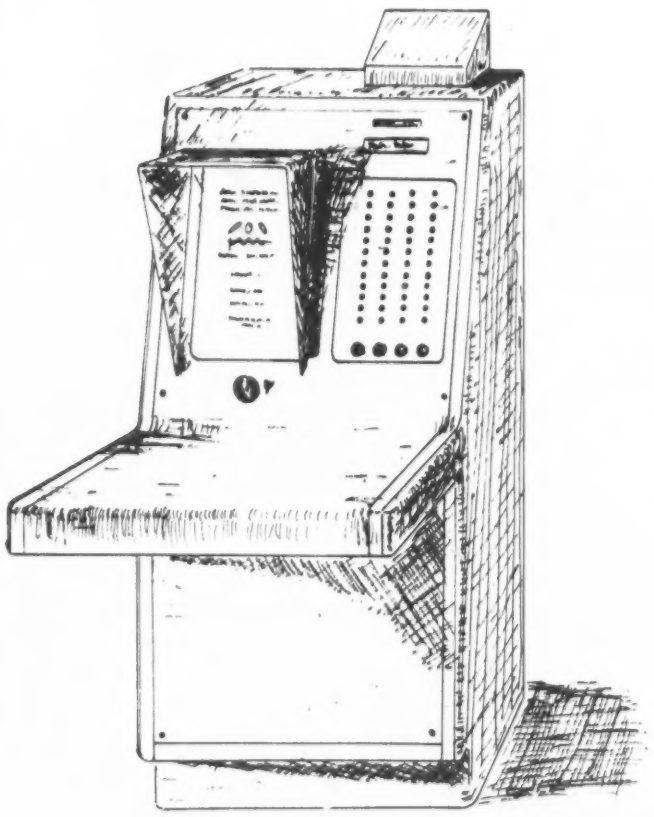


**Figure 64. Autotutor. Based on Crowder 1960 (Fig. 6).**

One of the most important developments in computer usage during the 1960's was the emphasis put on the use of time-sharing systems. This particularly affected the growth of computer-assisted instruction. By properly organized time-sharing, numerous users could use the same central processor from their own "terminal" stations. One of the best-known pioneer projects in educational time-sharing was that developed at Dartmouth College.

Another, far more recent, step greatly affecting the use of computers in education and individually-based experimental studies is the growth of the mini-computer industry. Among other things, this has the advantage that a small institution can afford a central processor which has the capability for peripheral equipment analogous to that which large-scale systems use, but which is smaller in size, capacity, and cost.

Numerous programming languages were either devised for the use of CAI directly, or adapted for its use. Among these, some of the earlier ones were BASIC, used with the Dartmouth-GE time-sharing system, and Coursewriter used with IBM systems.

CAI centers grew relatively fast during the 1960's. Among "pioneer" centers–in the sense that they date back to the early sixties–are the following: The University of Illinois Center, where a widely publicized program was developed using the so-called PLATO system, first with the University's Illiac computer, then with a CDC 1604 system. Stanford University, with the Institute for Mathematical Studies, began work on CAI in 1963. There the first cooperative public school program, the Stanford-Brentwood Project, was underway by 1964; the pioneer work done there in teaching mathematics and reading is well-known. The University of Pittsburgh in 1964 established a Learning Research and Development Center. This has had the two-fold aim of advising and supporting researchers in the technology of teaching, and of experimental work with CAI. Yet another relatively early center, established in 1965, at Florida State University, was tied to the Yorktown, New York, IBM Watson Research Center (Hickey 1968).

The work done by such centers has usually received support from manufacturers of equipment as well as Government agencies such as the Office of Naval Research, the U.S. Office of Education, and the U.S. Air Force. In addition, industrial firms such as International Business Machines Corporation and the Radio Corporation of America were active in CAI research in

the early 1960's, in addition to producing the pertinent hardware; particularly involved in CAI studies were research-oriented firms such as Bolt, Beranek and Newman and the Systems Development Corporation.

From the user's point of view, most CAI situations have involved the student's interacting with the computer program by means of a keyboard terminal that may have associated with it a miscellany of audio-visual equipment (Figs. 65-67). Occasionally, CAI is used in conjunction with a regular classroom situation to provide for individual response possibilities (Fig. 68). The programs vary in structure from the so-called linear programs of the Skinner type to branching and adaptive programs derived from the teaching machine suggestions of Crowder and Pask (1969). In addition, as computer flexibility has increased, other forms of programs, allowing freer verbal exchange with the student, have become popular. At the same time, there has been emphasis in some quarters on computer teaching games, and on computer simulation of problem situations (Hickey 1968).

Most computer programs are still designed to implement instruction in a particular subject field. Aside from training in computer operations and programming, the subjects creating chief interest, as measured by the number of new programs, are mathematics, the sciences, reading and spelling, and psychology. Although there are few experimental programs such as those at Harvard or MIT stressing studies of general learning and problem-solving, they generally receive less attention than the standard CAI projects which have generated a voluminous literature dealing with systems, techniques, philosophy, social implications, and other pertinent topics (Part III).

**Figure 66.** CAI with Audio Display and Keyboard Response.

**Figure 65.** CAI with Keyboard Display-Response.

**Figure 67.** CAI with Audio-Visual (TV) Display, Keyboard response

## 5. 1971-?: THE TECHNOLOGY OF MAN

Contemporary ideas of cognition have their roots in the variety of past interpretations. Unfortunately, these do not lead to something that is sufficiently solid to serve as a central trunk from which specific inferences may be derived. As a result, the term "cognition" is used to denote any number of concepts, not always well-defined, and not always compatible with one another.

Technology, on the other hand, is related to very concrete objects. Those objects that we consider as representative of the technological state of our times

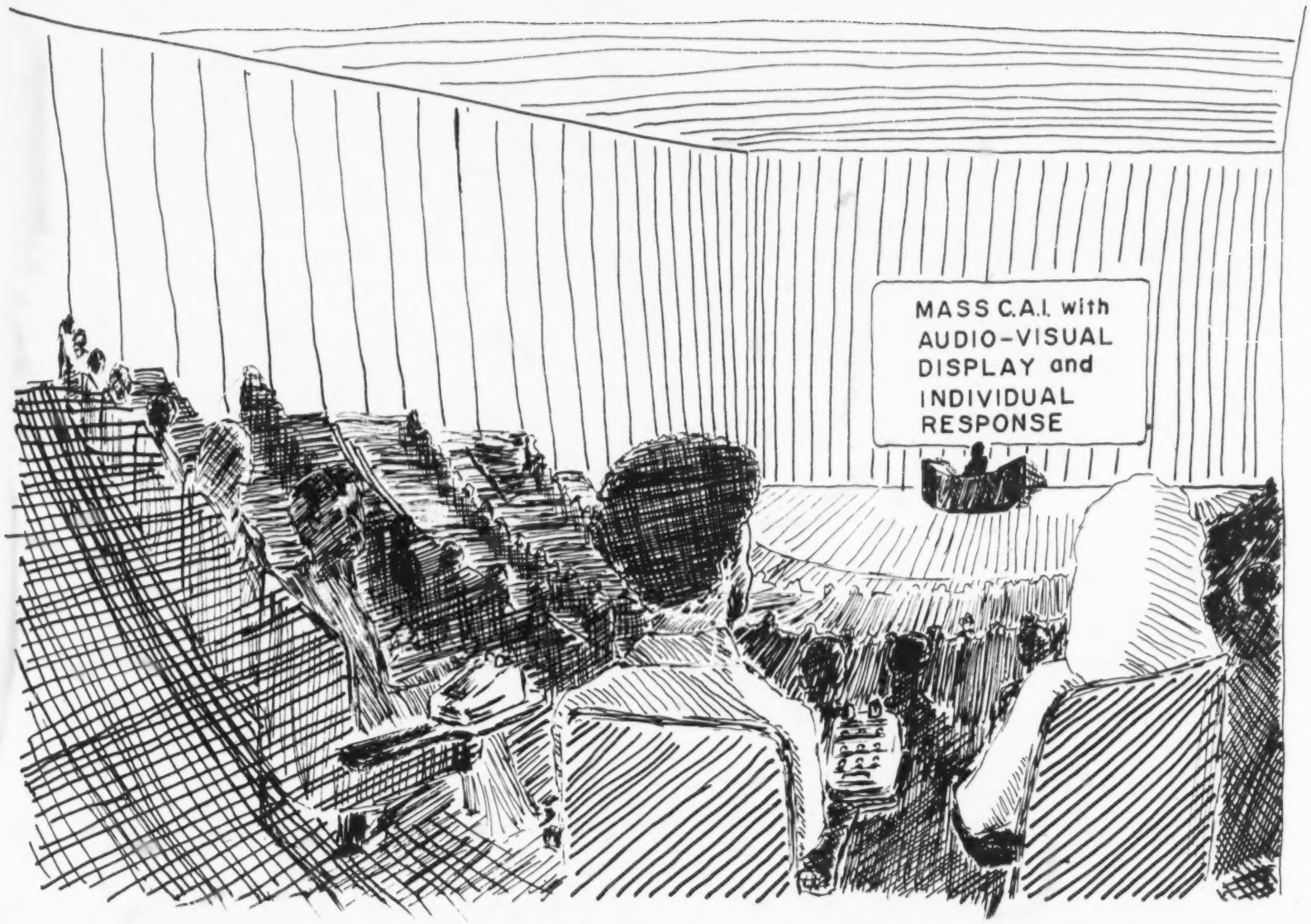



**Figure 68.** Mass CAI with audio-visual display and individual response.

have such tremendous potential for use that we find people in many areas of concern—including numerous ones that are far more clearly established than the field of cognition—hard-pressed to think of applications worthy of this potential.

The problem of finding appropriate means of technologically augmenting cognition is compounded further by the fact that under most interpretations of the concept "cognition" it is meaningless to speak of its augmentation. "Augmentation" pertains to quantitative increase. Unless one restricts the use of the term "cognition" to denote something like a stockpile of specific knowledge, it makes no sense to speak of its augmentation. Rather, most notions concerning cognition involve qualitative, non-measurable aspects, in addition to certain quantitative ones.

On surveying current projects supposedly devoted to the technological augmentation of cognition, one finds that they are engaged either in applying a new technological development to teaching traditional subject-matter; or, in applying such a development to traditional teaching techniques; or, in applying current technological products to subjects that are newcomers to the traditional curriculum; or again, in using accepted technological devices to test new teaching techniques. In other words, innovations in the so-called technological augmentation of cognition at present consist largely of combinations linking new and old teaching method, subject-matter, and technological product. This should not be so surprising or disappointing as it may appear. For, if one is concerned with "augmentation," one must stay close to that which is measurable; the combinations just sketched are so appealing because the investigator has under his control a vast array of tests and measures that he can apply to the subject, whether this subject be a student in the classroom, a listener/viewer of television, a visitor to a museum, or a piece of equipment.

The aspect of most present-day activities that is disappointing is the fact that they do not blend—except in a quite superficial way—current conceptual thinking about cognition with new laboratory results and techniques. The following topics are intended merely as examples of the way in which one can strive to technologically *enrich* human cognition, thereby supplementing the important work being done in technologically *augmenting* certain aspects of cognition.

From the wealth of recently developed concepts and techniques let us single out the following: (1) the view of cognition as a structuring process; (2) the notion that responses to stimuli may be regarded as the results of cognitive operations on elements; (3) the opinion that among cognitive operators one should treat separately linguistic and non-linguistic operators; (4) the suggestion that creativity and insight may be reflected in an individual's brain wave pattern; and (5) the experience that an individual may deliberately alter his wave pattern.

There has been a growing tendency during the past twenty years to think of cognition as a structuring process. Perhaps psychologists have been influenced by those modern mathematicians who came during the last century to think of their subject no longer as the study of quantity but as the study of structures (Bourbaki 1951). Whatever the reason may be, a number of scholars who differ on other points agree on emphasizing the importance of cognitive structures. Thus, Bruner writes the following:

> The structure of knowledge–its connectedness and the derivations that make one idea follow from another–is the proper emphasis in education. For it is structure, the great conceptual inventions that bring order to the congeries of disconnected observations, that gives meaning to what we may learn and makes possible the opening up of new realms of experience (Bruner 1965, p. 120).

Such an emphasis facilitates looking at cognition with primary regard to the operations that seem to characterize it, rather than being concerned exclusively with the quantitative measure that may be imposed. This accords with the later work of Piaget, and with most work dealing with the simulation of cognitive processes. In considering such operations, the distinction between linguistic and non-linguistic ones has, as was observed earlier, been impressed upon us by child psychologists, philosophers, anthropologists, and linguistic scholars. It has become more generally understood in recent years through work in technology, for example, that of pattern recognition. Despite all of this, these concepts are rarely applied in a direct way to the practical problem of enhancing human cognition.

Similarly, studies in the analysis of brain wave patterns have been conducted for forty years. During the last half of this period, there has been speculation and controversy concerning the relationship of these patterns to creative thinking and general behavior. Recently, reports concerning the possibilities of self-alteration of one's pattern have led to new flurries of speculation. However, in reviewing the extensive amount of research that has been accumulated on the subject of electroencephalography over the past four decades, it is striking how much work has been done in applying the technique to the–occasionally prematurely–attempted remedy of pathological problems, but how comparatively little research has been done in its potential applicability to enriching the learning process.

These selected examples may suffice to call attention to the difficulty that appears to characterize the present state of our subject. Today's powerful technology is applied to general learning within a conceptual framework that was well-established about a half-century ago. "New" thought is occasionally superimposed on this. But there is little effort to integrate major modern conceptual trends with apparently sound principles of established methods or apparently fruitful products of recent technological advances. Neither the so-called "man-on-the-street" nor the average educator has any idea of the applicability and potential importance to his everyday occupations of recent work in linguistics or in artificial intelligence, for example. If there is such awareness, it tends to be clouded by misconceptions, myths, and fears about formulas and machines.

One may guess that more Americans can identify Karel Capek than Warren McCulloch. This, however, is not to be regarded as a problem of separate, multiple cultures. It is a problem of keeping an eye on at least a few of the major strands that make up the fabric of our present culture. One effective aid in solving this problem is the historical exhibition, the subject of Part II of this document.

# PART II – EXHIBITION MODEL

## 1. THE LARGE-SCALE EXHIBITION

For convenience it will be assumed that the exhibition is located in one large area, roughly square or rectangular in shape. Clearly the shape of the available area need not be a major factor; indeed, the exhibition about to be described can easily be adapted to other spatial configurations. It will be assumed that the visitor is to be encouraged to follow a specific direction, rather than to wander about the exhibit haphazardly; that is something that can be accomplished with relative subtlety by an appropriate design.

There are two basic principles underlying the design of the exhibit: The first is that the exhibit is intended to display the history of the subject; because of this, there is considerable emphasis on temporal sequences. The second one is that, as far as possible, the techniques and technological products of a specified period are to be used to portray the devices of that period; there is, in other words, considerable emphasis on objects being used to describe themselves.

As has been seen in the discussion of Part I, certain types of objects and techniques are particularly characteristic of given periods, although they may have been important before that time, or remain so after the period in question. The present plan attempts to reflect this by

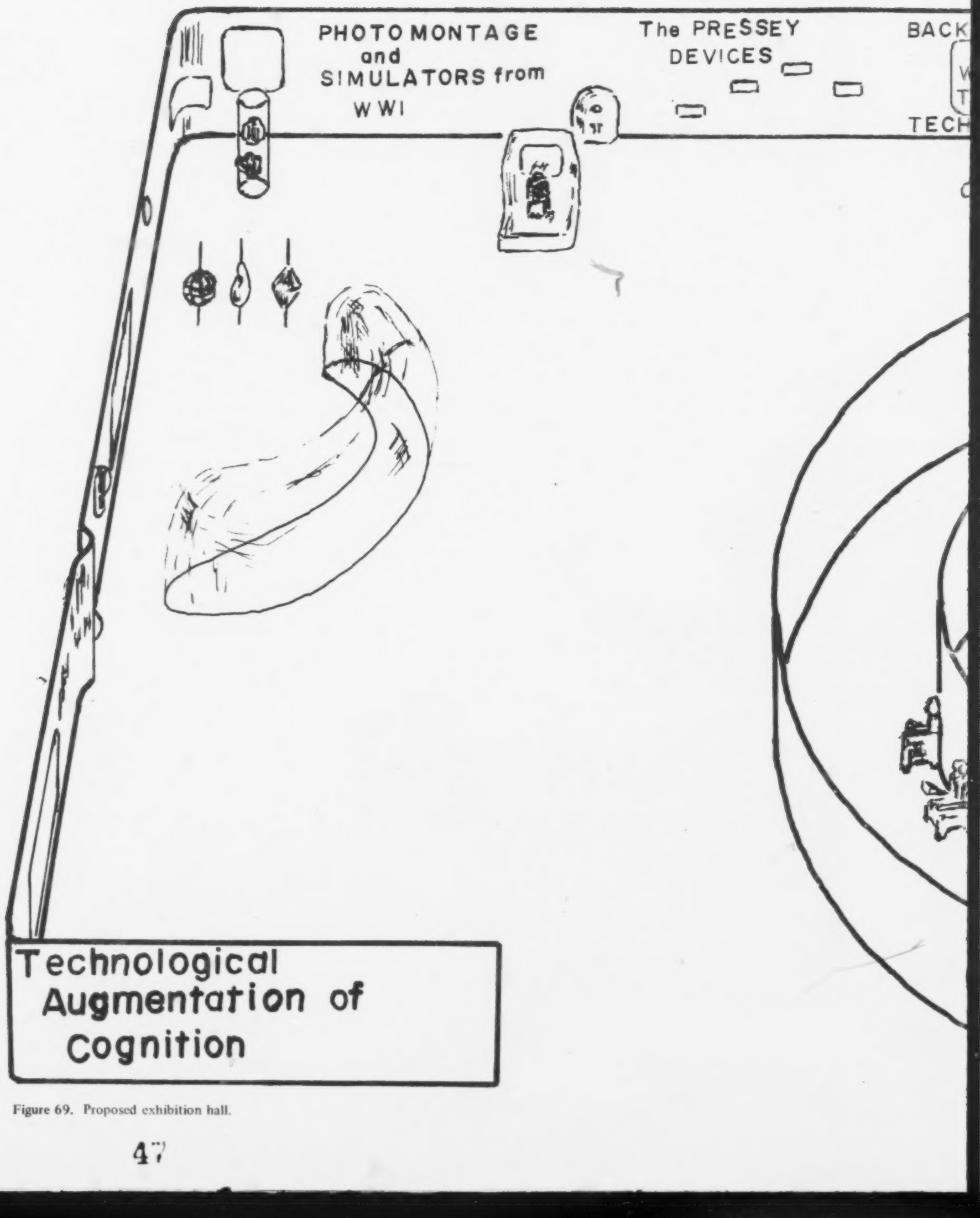
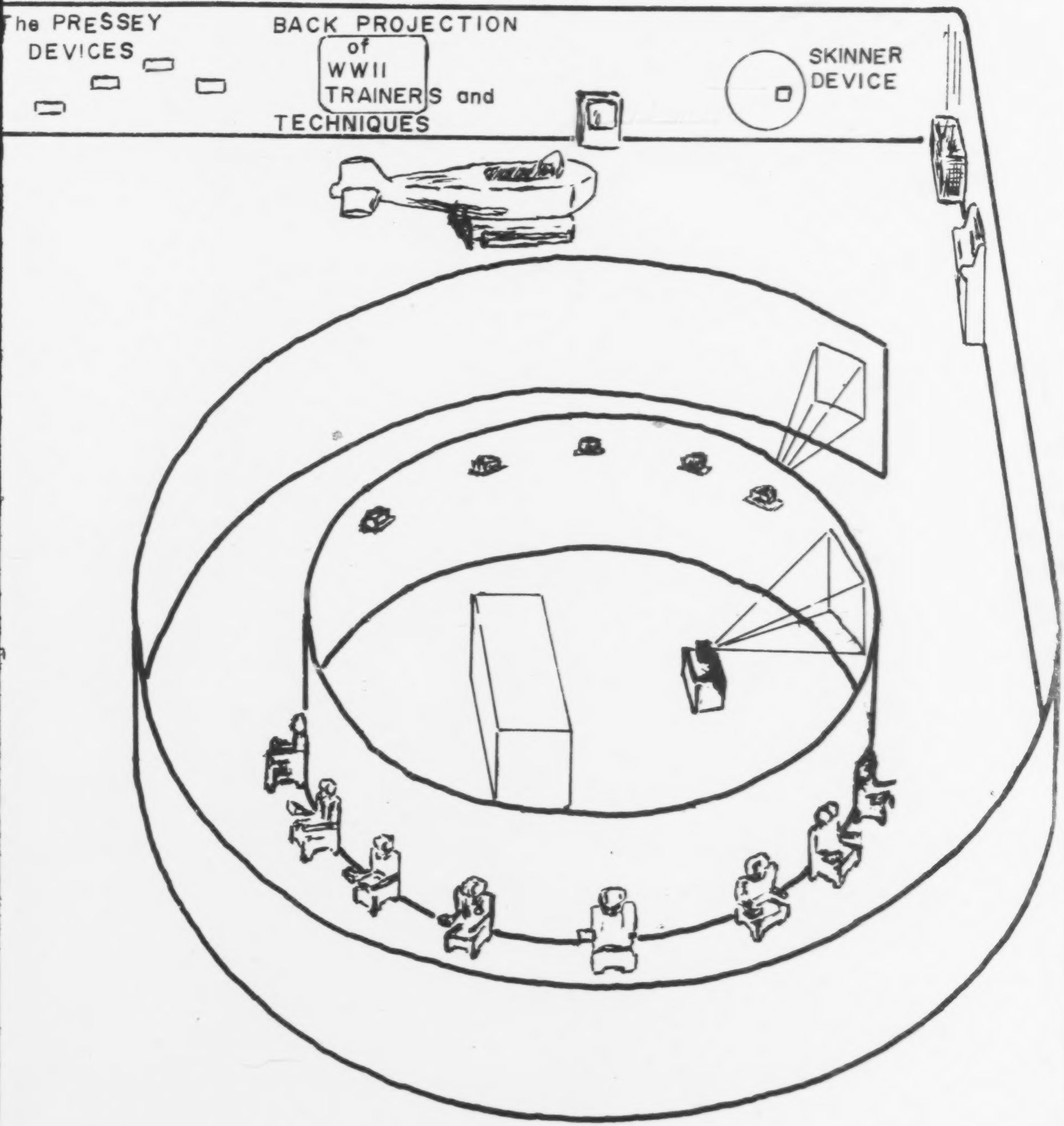



Figure 69. Proposed exhibition hall.


The PRESSEY DEVICES
BACK PROJECTION of WWII TRAINERS and TECHNIQUES
SKINNER DEVICE

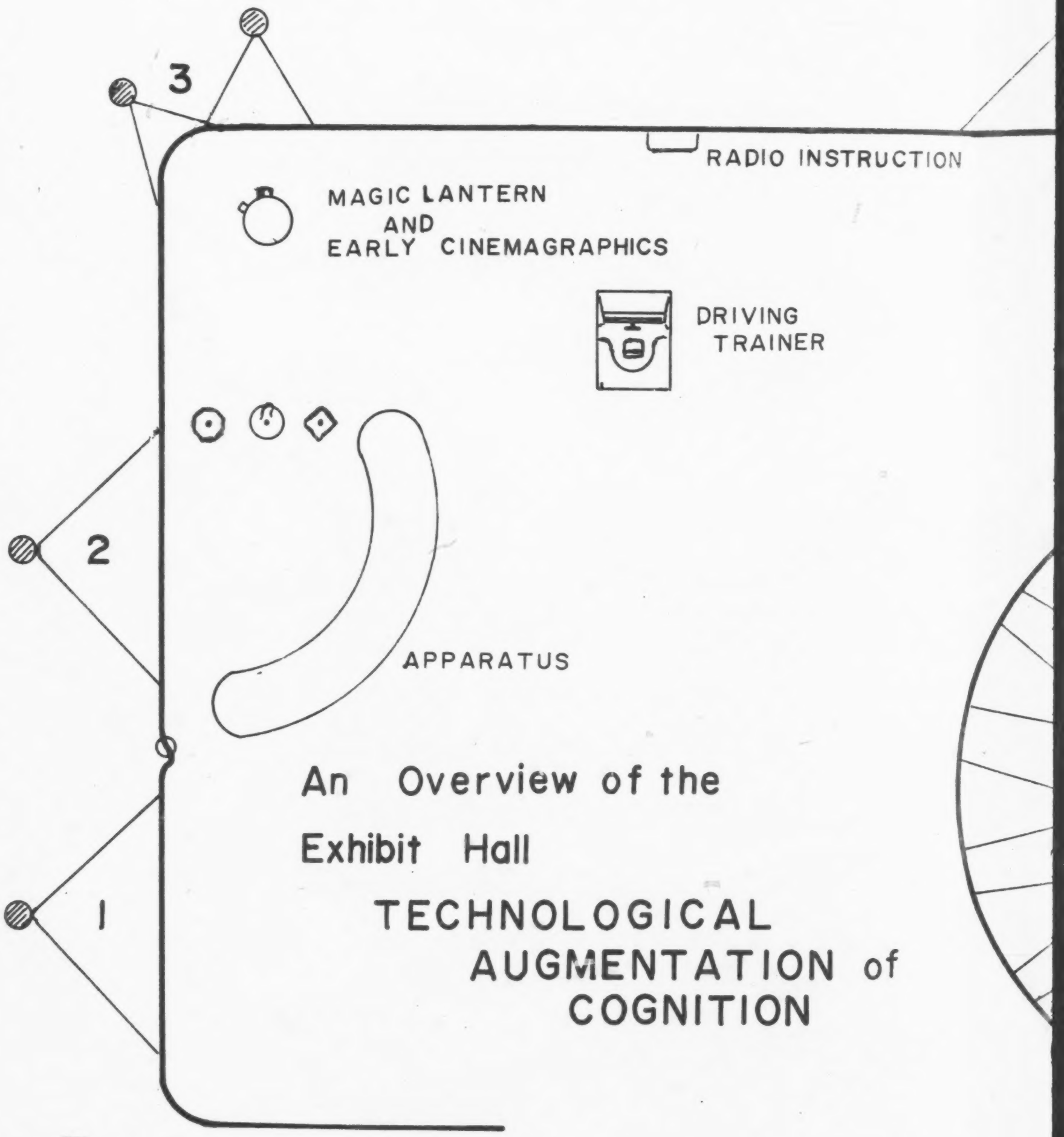



Figure 70. Proposed exhibition hall (overhead view).

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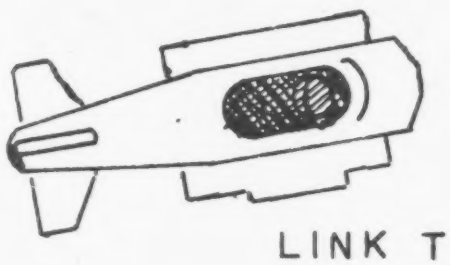
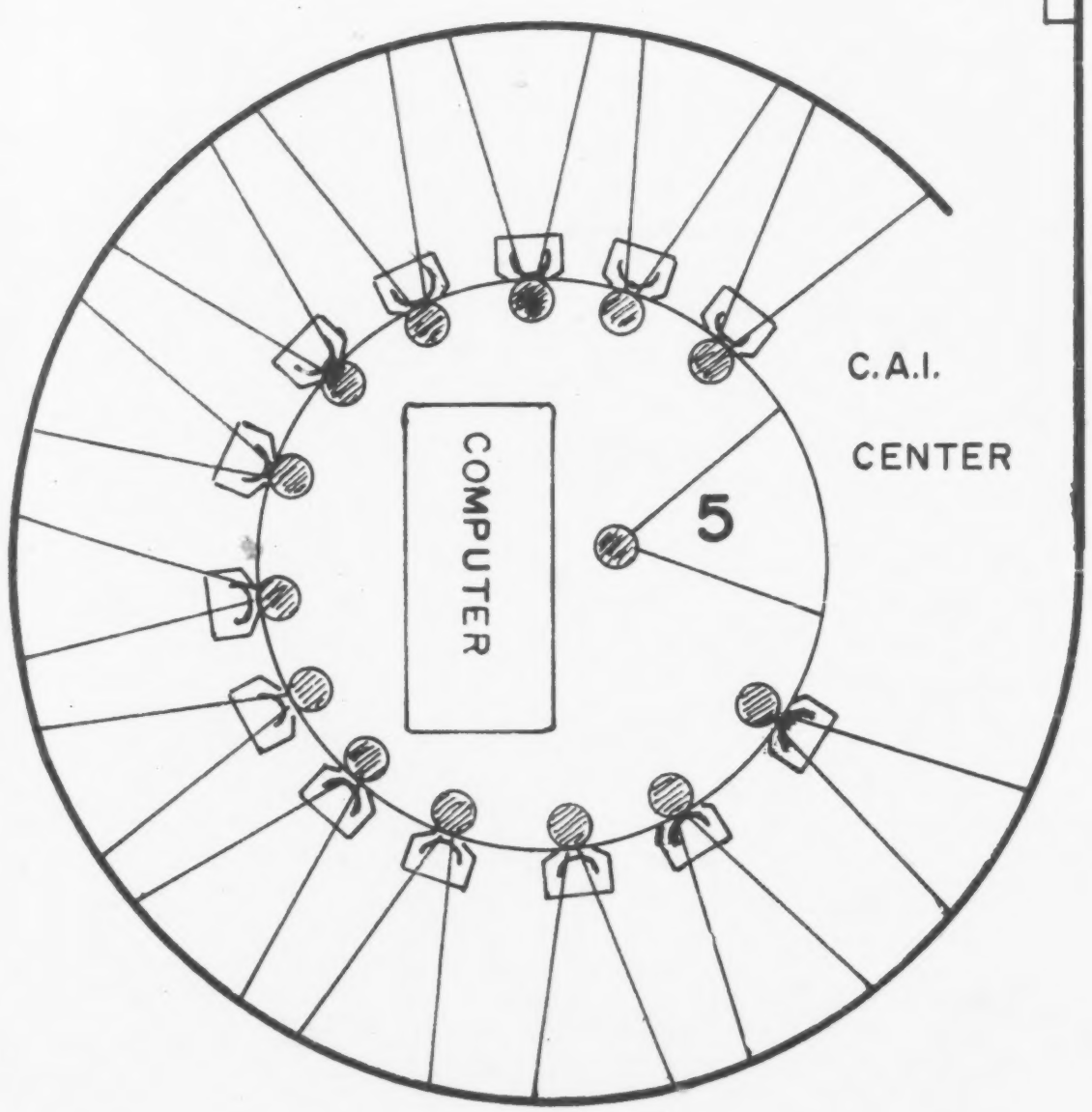


LINK TRAINER

AUTOTUTOR

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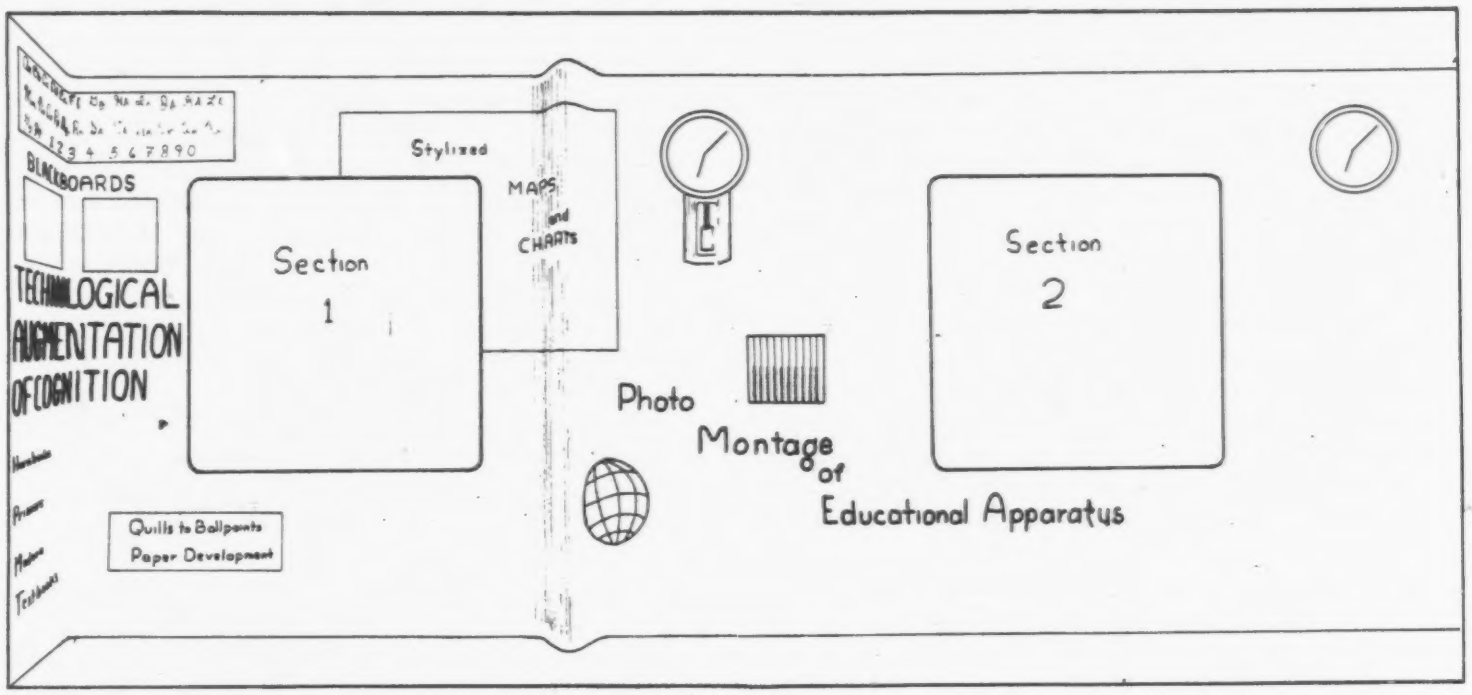


Figure 71. Exhibition hall; first part, to 1900.

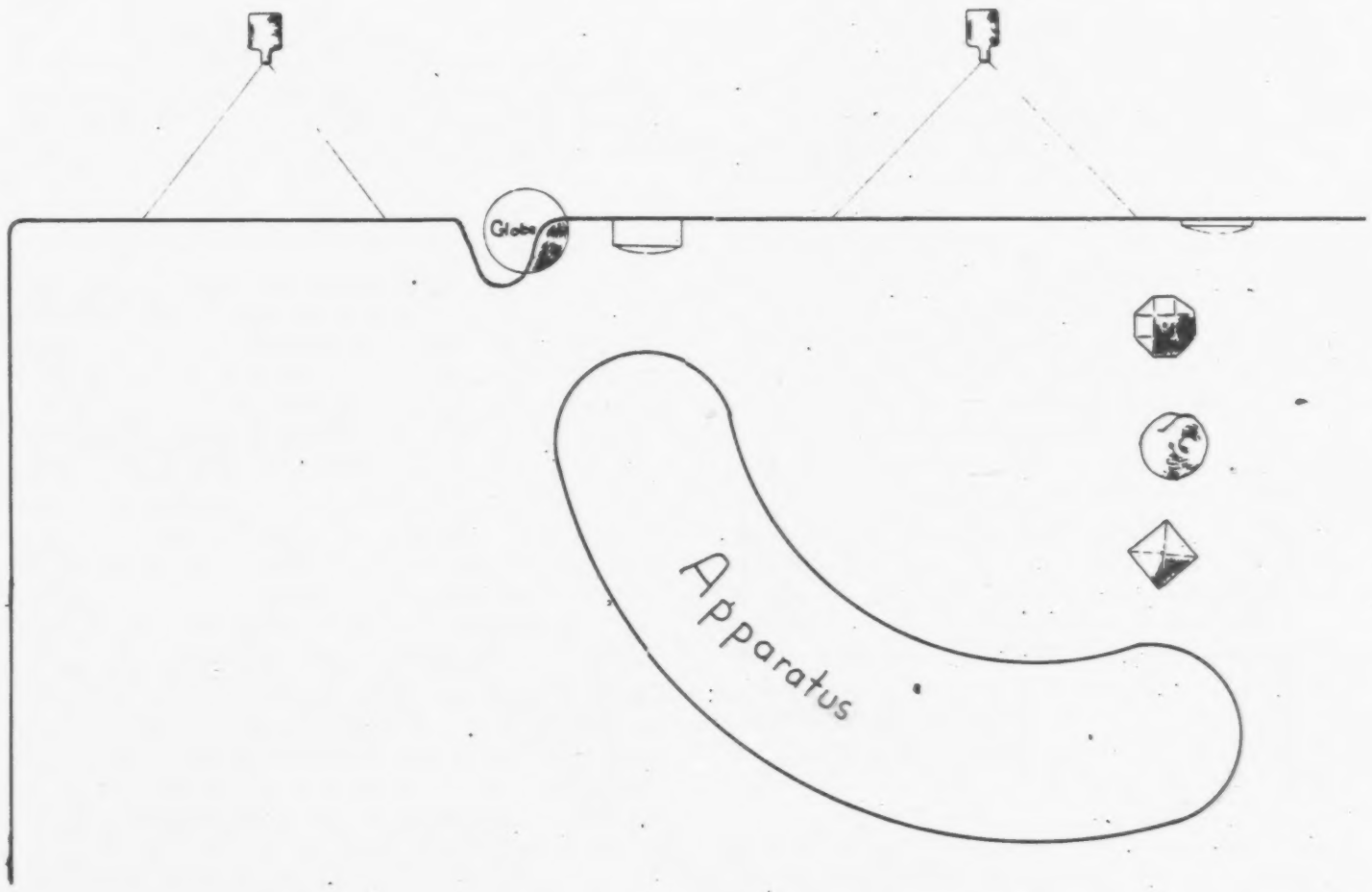


Figure 72. Exhibition hall; first part, to 1900 (overhead view).

emphasizing the story of those devices in the context of the period with which they are particularly associated. Thus, the exhibition treats the development of the textbook and of printing and publishing techniques in considerable detail in the context of the nineteenth century, but only refers on a secondary level to later developments in that area; for example, wide-spread use of the rise of pocketbooks in recent times is given less prominence than the growth of the use of television and of the computer during the same period.

Having obtained a general impression of the exhibition (Figs. 69 and 70), it may be helpful to examine the various parts in some detail.

Proceeding in a counter-clockwise direction from the entrance, one first encounters the items we have associated with the "fact-oriented" period in our history (Figs. 71 and 72). There are the objects used by the citizen-at-large: broadsides, books, newspapers, weeklies, and other periodicals. Then, there are the objects of the primary classroom: the tools of reading and spelling–hornbook, battledore, primer and textbook; the tools of writing and penmanship–pens (from quill to steel), ink and inkwell, blackboards, slates, and paper; the tools of arithmetic–charts, objects, time pieces and numeral frames; the tools of geography–charts, maps, and globes. There are the objects of the college and secondary school, such as science teaching apparatus; and finally, there are the devices pertaining to subjects not necessarily cultivated in the schools, such as music and drawing, as well as special inventions. The exhibit attempts to portray separately the technological and functional aspects and varieties of each of these; this is done by replacing the standard types of labels by explanations suggesting the form and technique of the period: For example, clear hand-writing on large sections of blackboard is used to call attention to the differences in size and type of material that characterized changing techniques in blackboard construction; contemporary books on the use of the blackboard are opened to pertinent passages. In addition, reading tables containing reproductions of other contemporary discussions of the material shown may be placed near this portion of the wall. Finally, these isolated stories of specific devices are brought together in one or more period rooms set into the wall at the center of this first section. Either one room may be depicted, or, a variety of settings can be shown by using a rotating platform. In either case, it is desirable to have appropriate seats for the visitors that appear to form a portion of the room. Here one may sit and absorb the atmosphere of the period while listening to a docent, in appropriate period dress, provide more detailed explanations of this portion of the exhibition; this docent assumes the role of the teacher, lecturer, or demonstrator, depending on the type of setting the period room depicts.

Moving into the next section, one finds exhibits of kindergarten materials, showing the use of the orthodox Froebel "gifts" as well as the spread of educational toys. Photographs reminiscent of the period show children at play with devices such as those represented. Further along, there is a series of stereoscopes through which one can view scenes from some of the great expositions of the late nineteenth and early twentieth century; these scenes include displays pertaining to the subjects of interest in the present context.

Beyond this, one slips into a rather intimate "amphitheater" bounded in part by a spacious exhibit case that sweeps into the center of the hall with a gentle curve; on the side, the area is bounded by an ultra-modern "Froebel gift" consisting of three large plastic solids–perhaps a duodecahedron, a pyramid, and a Klein bottle –that are hung from the ceiling, but are free to revolve and move. These gifts are hung sufficiently low so that they can be touched and investigated by young and old.

Within the "amphitheater" are exhibits of instructional and experimental apparatus pertaining to the study of cognitive processes. The setting is somewhat reminiscent of an early twentieth century laboratory. A docent demonstrates some of this apparatus using visitors as subjects.

Passing beyond the "Froebel gift" one now encounters examples of early visual materials: Magic lanterns are described by projection from a magic-lantern-like device; film strips and silent motion pictures again are used to describe themselves. Various examples of these are exhibited in an adjacent case. It should be noted that whereas it is desirable to show the actual objects if available, replicas should be used for most demonstrations here and in other parts of the exhibition. Thus, a magic lantern may appear to project the appropriate pictures the wall; in fact, these will probably be produced by back-projection. Other "gimmicks" could be introduced as well. For example, it may be highly effective to reproduce the characteristic smell of the magic lantern in action.

Moving along the back wall, one passes examples of various training and testing devices designed for military and civilian purposes. Again, projection equipment of the period may be used to provide information about these devices. Here one also finds presentations of World War I training films, as well as other films of the period used in a pertinent context.

Proceeding along the portion devoted to the 1920's, one encounters sound: There is an early radio reproducing the era of pioneer educational broadcasting. Away from the wall, flanking the radio, are two operational trainers, a driving simulator and a Link flight trainer; these are both available for first-hand inspection. Returning to the sequence along the wall, there is a series of devices representing the contributions of Pressey and his students to automatic teaching. In front of these are larger replicas which may be operated to learn about the history and use of the devices; for example, the first Pressey machine may be described on an activated model by a sequence of multiple-choice questions and responses.

An audio-visual presentation next serves to introduce the visitor to the contributions of World War II to the technology of cognition; this is supplemented by appropriate objects. In this area, it will be necessary to use

ear phones as the use of sound now increases. For only a few feet away there is a TV set presenting a program on the early history of television and "educational" television.

At last, the visitor has reached the period of the modern teaching machine. A large Skinner device introduces itself and upon being operated by the visitor explains the philosophy and uses of modern teaching machines. A device such as the Autotutor may be used to provide an introduction to the development of branched programming. Depending on the availability of actual devices, any number of special-purpose teaching machines may be used for self-operated interactive demonstrations. In addition there may be up-to-date simulator such as those used in technical school instruction or in the space program (Fig. 73).

Finally, the rotunda is reached. This is devoted to portraying the development and status of computer-assisted instruction. The visitor obtains this information through computer-assisted instruction. The following construction is recommended (Fig. 74).

The interior structure is designed to provide both a portable enclosure for the computer and instructional equipment, and an individualized area for maximum visitor involvement. The structure itself is a light opaque plastic material which is kept inflated by the same air conditioning which maintains the clean, thermally stable atmosphere for the computer. The instructional chair for the visitor has a headrest providing comfort and limitation of the field of vision. In addition, audio headphones are located in the headrest to provide an audio display for the instruction program. Armrests for right and left-handed visitors should be provided.

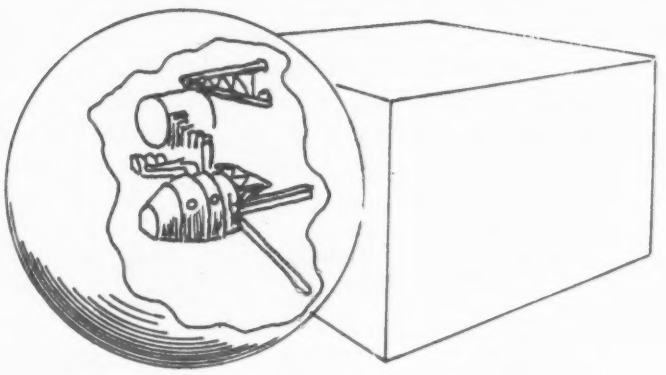

**Figure 73.** N.A.S.A.'s Space Environment Simulator.

The CAI exhibit offers a choice of topics to the visitor. These include lessons on the history of CAI, on work being done at major CAI centers throughout the

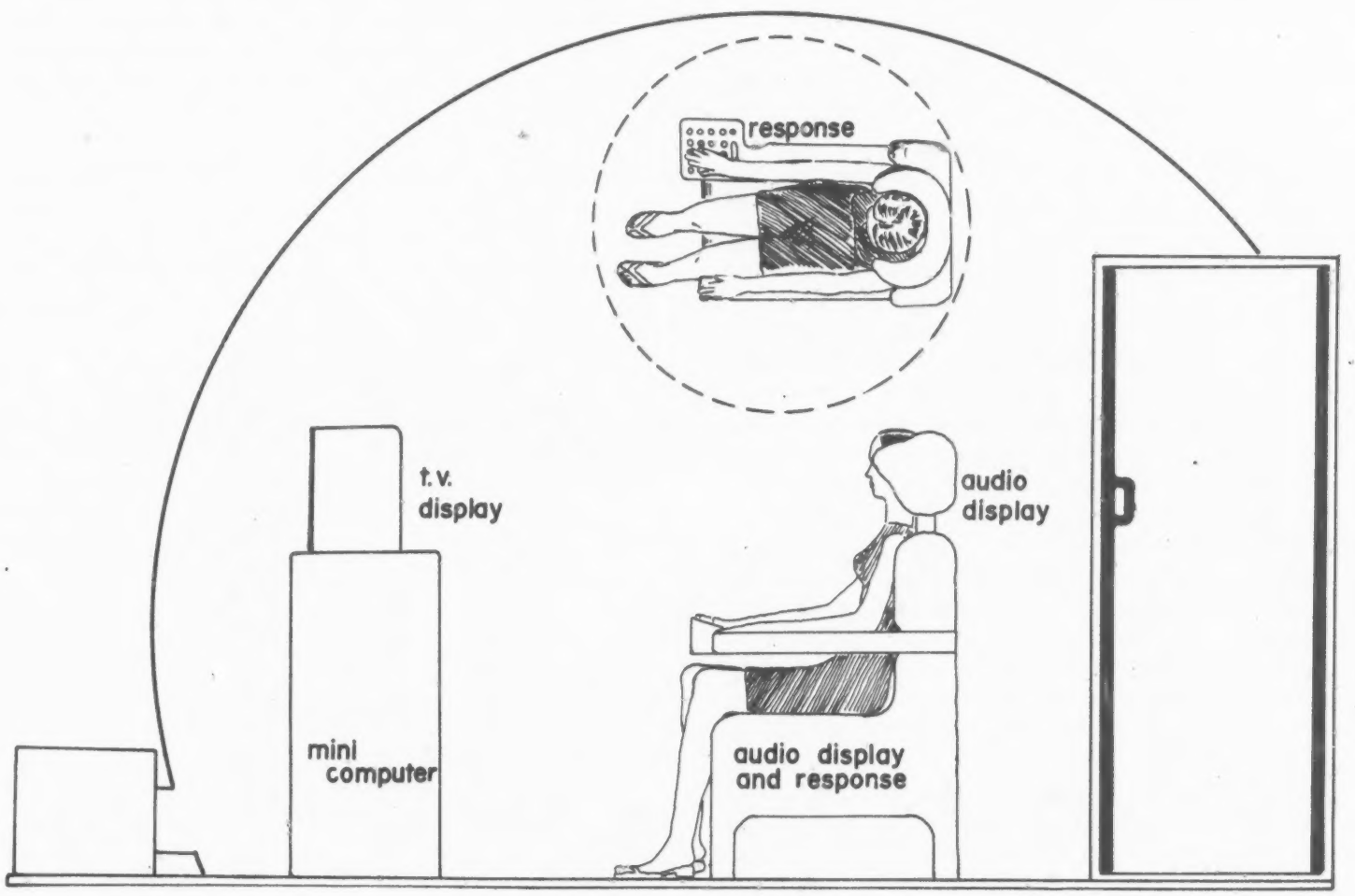


**Figure 74.** Exhibition hall; portable enclosure (including overhead view)

country, and on programs developed for specific subjects. In addition, it is desirable to present typical programs used in area schools, and to provide opportunities for the visitor to write his own program.

Thus far, the visitor has been exposed to fact-oriented technology with the help of a docent relating information; to process-oriented technology with the help of either a docent or a device demonstrating a sequence; to communication-oriented technology with the help of a medium such as a radio or motion picture; and to machine-oriented technology with the help of a self-operable machine. It is effective to conclude the exhibit by letting the visitor demonstrate himself to himself. For that purpose, a functional electroencephalograph may form an interesting conclusion to the exhibit. On the outside of either the exhibit case forming a portion of the "amphitheater" or of the rotunda—depending on the over-all dimensions of the total exhibition—an electroencephalograph arrangement may be located, which will allow the visitor to see and hear his own wave pattern. In addition, it may give him a brief introduction to the self-manipulation of this pattern.

## 2. MODIFICATIONS OF THE LARGE-SCALE EXHIBITION

The exhibition just described can obviously be modified in numerous ways. First of all, in most locations there will not be sufficient original source material to represent all the major varieties of objects by original examples. Hence, it may be necessary to use models, replicas, or illustrative materials. Instead of using period-oriented projections, a great deal of historically revealing information can be conveyed by the use of standard modern back-projection techniques. In addition, the use of standard graphics—which, although not mentioned explicitly, is taken for granted as a supplementary technique in the exhibition described—can be increased where other methods are inapplicable. There are other methods that may be used effectively when the variety of techniques suggested is unfeasible. Among these, it will suffice for the present purpose to single out the use of holograms, the use of pure audio-visual techniques, and the exclusive use of CAI.

### THE HOLOGRAM

The hologram provides a particularly simple and effective means for presenting objects too rare or expensive for exhibition. In addition, it illustrates one of the more interesting current devices used to "augment cognition." A cylindrical hologram is capable of giving the complete illusion of a three-dimensional object. Especially intriguing is the use of moded polarized light to present a sequence of objects—or a fully three-dimensional moving picture—for display from one hologram.

The hologram ("complete picture") is a photographic image of an entire interference pattern of light intercepted in space, usually at some distance from an image of interest. In other words, it is the image of light just as the eye would perceive it, and having all the potential information that the eye would receive, if it were to move in space along the surface of the hologram. The major requirement for producing a hologram is that the light used to illuminate the subject under study and to examine the hologram be in phase; that is, the light must be emitted from the source at precise intervals (Laser light); otherwise, as in normal daylight, the wave fronts of light will be washed out and made indistinct, much as the difference between the ocean waves and waves generated in a pool by regularly dropping pebbles in it. Each piece of the hologram is capable of reproducing the image imprinted on it in exactly the same way that a small hole, opening into a room, allows us to perceive the objects in that room. The suggestion we made here for creating multiple images on one hologram is that in addition to being in phase, (coherent) light used to expose a hologram should also be moded or polarized, that is, be polarized in various planes vibrating in one plane. By selectively illuminating the hologram with light, different previously recorded images may then be generated from one hologram (or by using three polarized sources of different colors, a full color image may be generated). This technique is much like peering through the hole into our room with polarized glasses while objects are successively illuminated with plane-polarized light.

The illustrated exhibit (Fig. 75) is based on the use of any one of a wide number of commercially available mode-adjustable lasers in a configuration which allows

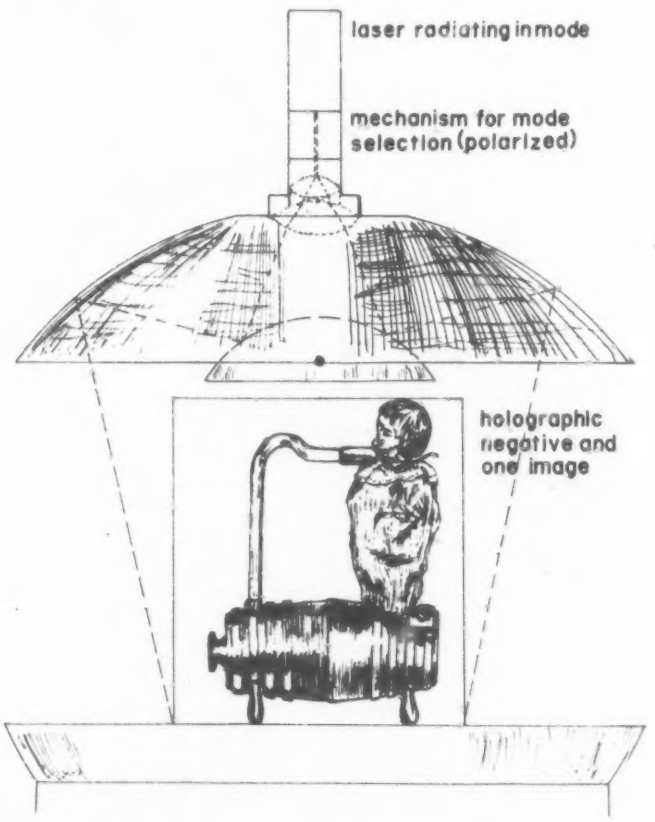


**Figure 75.** Hologram; for exhibition use

for a 360 degree examination of the image. It should be noted that the same technique of using polarized laser light would allow the presentation of full color images, namely, by using three differently colored lasers in three different modes.

### AUDIO-VISUAL EXHIBITION

The large-scale exhibition described above can be partly or fully condensed into an audio-visual exhibition. The illustrated designs (Figs. 76 and 77) show one form of such an exhibit, which has the particular advantage that it can be used in any available area. It thus lends itself particularly well to traveling exhibitions. The acoustic isolaters are simply acoustic tile on a panel backing while the rest of the structure consists of inexpensive light paneling and wooden framing.

### CAI EXHIBITION

If either a minicomputer is available, or a set of consoles tied to a central computer that allows for program insertions, the whole exhibition can be displayed through the computer system in question. It is desirable, of course, that this system have both audio and visual display possibilities. Given such a system, all the material in a large-scale exhibit such as that just described can be reproduced. In addition, astute programming can be used not only to call forth the historically interesting devices, but some of the theories that are related to these devices; furthermore, the programs can be designed to illustrate different teaching techniques that are of either historical or practical interest.

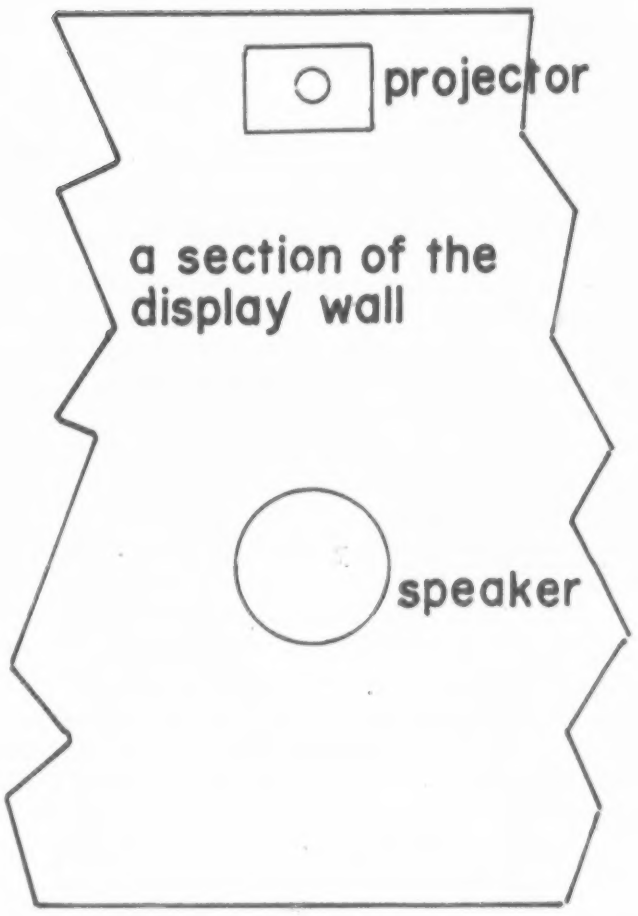


**Figure 77.** Medium-sized audiovisual exhibit (side view).

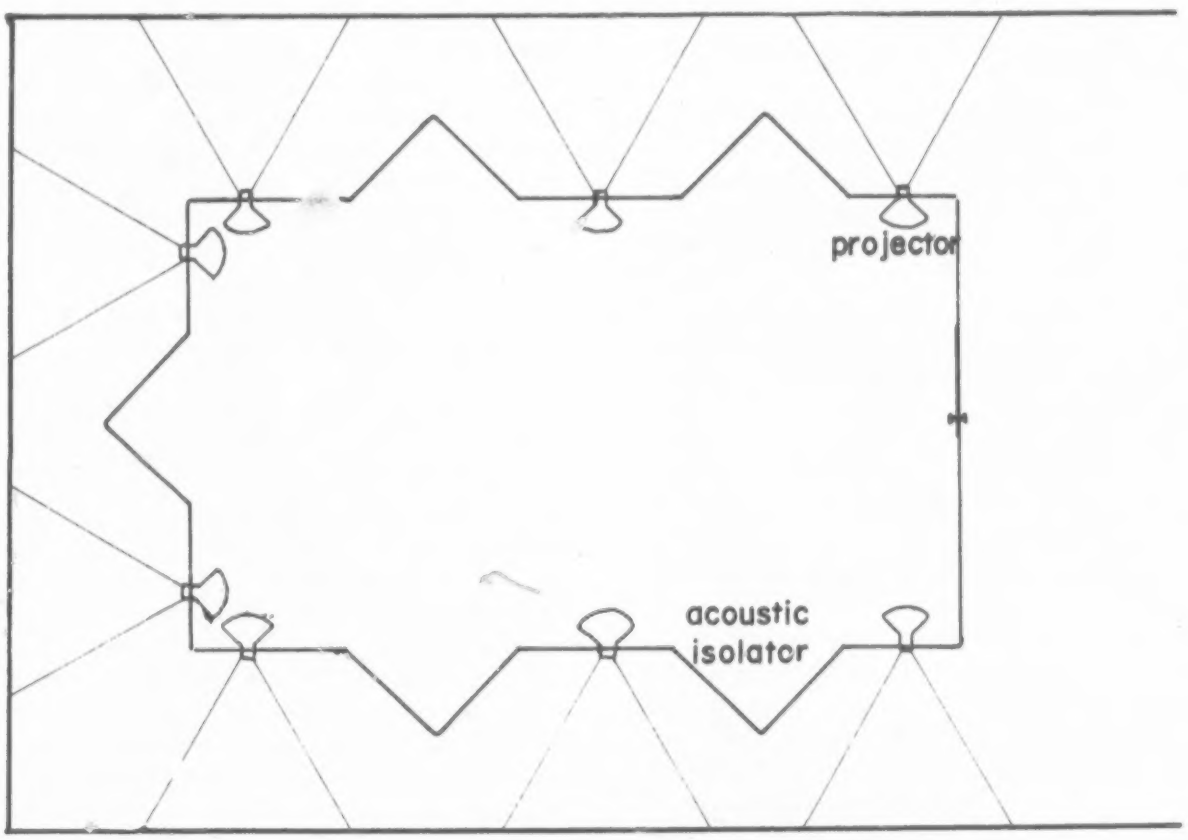


**Figure 76.** Medium-sized audiovisual exhibit (overhead view).

# PART III – CONSIDERATIONS FOR STUDY

## GUIDE TO SOURCE MATERIALS

The publications referred to in the following have been selected because they provide particularly rich reference material or because they are easily accessible.

The traditional problem of knowledge is discussed in most standard histories of philosophy; Windelband 1958 is a good source. Topics pertinent to the concept of cognition in the United States are treated in Boorstin 1948 and Miller 1961 and 1965, among others. Boorstin 1965 has a wide bibliography; Nye 1960 contains many useful references.

Boring 1929 remains the classic treatment of the history of psychology, particularly valuable for the United States; it is complemented by Stevens 1951 and Thomson 1968. An overview concerning recent attitudes toward cognition may be gained by consulting the following: Colorado 1957; Harper et al. 1964; and Garvin 1970.

Among histories of education, Brubacher 1947 is one of the few that takes into account the use of objects; Brubacher 1969 lacks illustrations of apparatus found in the earlier edition. Wesley 1957 has a far broader treatment of the history of education in the United States than the title implies; it includes considerable treatment of the discussions pertaining to object teaching in the nineteenth century. Cremin 1970, with a fine bibliography, appears definitive for the colonial period.

There are two studies dealing specifically with the history of technology in education: Anderson 1962 is an interesting compilation of primary references; the account in many places follows that of the source material verbatim. Saettler 1968 is strongest in discussing the audiovisual movement.

Histories of technology do not deal with many of the objects we have considered. Hindle 1966 and Pursell 1969 are somewhat exceptional in this respect. However, standard histories such as Hall et al 1958 or even Oliver 1956 should be consulted. Porter 1957 gives a useful introduction to teaching materials of the first half of the twentieth century. Lehmann-Haupt 1939 and 1951 presents an interesting survey and bibliographic guide to the technology of reading. Bedini 1964 provides a very helpful introduction to American scientific instruments used in teaching; Fleming 1952 gives a rare example of a local case study. The instruments of psychology are described in standard treatments of experimental psychology such as Titchener 1901 and 1905 for the early period, and Woodworth 1938 plus Woodworth and Schlosberg 1954 for more recent times. Andrews 1948 contains an extensive bibliography. Other important sources are manufacturer's catalogs such as Zimmermann 1912 and Stoelting 1936. Popplestone and McPherson 1971, calling attention to the need for further study, provide other references.

Mellan 1936 attempted to call attention to the study of patents simply by listing several hundred pertinent patent numbers. The work remains to be done. The most important group of materials is U.S. Patent Office Class 35.

Our chapter 4 is intended to be read in conjunction with Lumsdaine and Glaser 1960 and with Hickey 1968. Lumsdaine and Glaser 1960 has an excellent cross-section of source material on programmed learning and teaching machines, together with an important annotated bibliography and an extensive list of references. Hickey 1968 presents a splendid survey of the development of CAI in the 1960's, together with appropriate references to the literature. Other materials useful in relation to this chapter are Foltz 1961, which presents an interesting survey of teaching machines available about 1960; and Glaser 1965, which is a continuation of Lumsdaine and Glaser 1960. Lekan 1969 and 1970 contain descriptions of existing CAI programs; they are similar to the listing issued in card form by ENTELEK Inc. Other useful state-of-the-art indicators are the following symposia compilations: Galanter 1959; Coulson 1962; Sass and Wilkinson 1965; Annett and Duke 1970; and Holtzman 1970.

With regard to related topics, Annett 1969 presents a very comprehensive but rather little-known guide to studies of knowledge of results and other issues in learning. Woelfle 1951 and Bilodeau 1966 are recommended as introductions to topics in training since World War II. For detailed studies of contributions made in the two world wars, the appropriate record groups in the United States National Archives are valuable.

The tremendously important areas of neurophysiology, information theory, linguistics, and artificial intelligence have been deliberately omitted from the present discussion. However, a basic knowledge of recent activities in these fields should be considered indispensable for a serious student of our subject. In addition to the well-known works of Norbert Wiener (1948 and 1956), the following provide a cross-section of introductions to these areas: Pierce 1961; Feigenbaum and Feldman 1963; Reitman 1965; McCulloch 1965; Minsky 1967; IBRO 1968; and Meetham and Hudson 1969.

Among other aspects of cognition not covered in the present study is the role of symbolism. This is discussed in Langer 1967, where further pertinent references will be found.

Numerous source materials that are basic to studies in this field have not been listed here. Among these are the pertinent writings of influential persons such as

William James or John Dewey; the numerous early journals on education that carry detailed discussions of school equipment and apparatus; various catalogs of manufacturers specializing in scientific, photographic, electronic, educational, psychological, and other materials; and the detailed reports of exhibitions and expositions that featured objects illustrating the technological augmentation of cognition. Finally, little has been said about the location of extant objects: indexes of these are maintained in various parts of the National Museum of History and Technology.

## REFERENCES


Adams, W. J. 1830. Lecture on the construction and furnishings of school rooms; and on school apparatus. *American Institute of Instruction* (Boston), pp. 333-46.

Anderson, C. 1962. *Technology in American education 1650-1900.* U.S. Office of Education. Bulletin No. 19.

Andrews, T.G. 1948. *Some psychological apparatus: a classified bibliography.* Washington, D. C.: The American Psychological Association, Inc.

Annett, J. 1969. *Feedback and human behavior; the effects of knowledge of results, incentives and reinforcement on learning and performance.* Baltimore: Penguin Books.

Annett, J., and Duke, J., eds. 1970. *Proceedings of a seminar on computer based learning systems.* London: National Council for Education Technology.

Arps, G. F. 1917. A preliminary report on 'work with knowledge versus work without knowledge of results.' *Psychol. Rev.* 24:449-455.

Arps, G. F. 1920. *Work with knowledge of results versus work without knowledge of results, awareness and partial awareness as factors conditioning efficiency.* Princeton: Psychological Review Co.

Bedini, S. A. 1964. *Early American scientific instruments and their makers.* Washington, D. C.: Museum of History and Technology, Smithsonian Institution.

Bilodeau, E. A., ed. 1966. *Acquisition of skill.* New York: Academic Press.

Boorstin, D. J. 1948. *The lost world of Thomas Jefferson.* Boston. Beacon Press.

Boorstin, D. J. 1965. *The Americans: the national experience.* New York: Random House.

Boring, E. G. 1929. *A history of experimental psychology.* New York: Appleton-Century.

Bourbaki, N. 1951. *Elements de mathematiques.* 2nd ed. Paris: Herman.

Bray, C. W. 1948. *Psychology and military proficiency: a history of the applied psychology panel of the National Defense Research Committee.* Princeton: Princeton University Press.

Brown, D. 1966. Chapter 5 in *New Horizons in Psychology,* ed. B. M. Foss. Hammondsworth: Penguin. Cited in Thomson 1968.

Brubacher, J. S. 1947; 1969. *A history of the problems of education.* 1st and 2nd ed. New York: McGraw-Hill Book Co.

Bruner, J. S. 1962, 1965. *On knowing: essays for the left hand.* New York: Atheneum. Reprint of Cambridge: Harvard University Press.

Bush, R. R. and Mosteller, F. 1955. *Stochastic models for learning.* New York: John Wiley & Sons, Inc.

Cattell, J. McK. 1900. *On the wheel chronoscope. Psychol. Rev.* 7:333. Cited in Titchener 1905.

Colorado University, Psychology Dept. 1955; 1957. *Contemporary approaches to cognition; a symposium held at the University of Colorado.* Cambridge: Harvard University Press.

Coulson, J. E. ed. 1962. *Programmed learning and computer-based instruction.* Proceedings of the conference on applications of digital computers to automated instruction. October 10-12, 1961. New York: John Wiley and Sons, Inc.

Cremin, L. A. 1970. *American education: the colonial experience 1607-1783.* New York: Harper & Row.

Crowder, N. A. 1960. Automatic tutoring by intrinsic programming. In *Teaching machines and programmed learning,* ed. Lumsdaine, A. A. and Glaser, R. Washington: DAVI National Education Association.

Deutsch, J. A. 1960. *The structural basis of behavior.* Chicago: University of Chicago Press.

Dewey, J. 1896. The reflex arc concept in psychology. *Psychol. Rev.* 3:357-70.

Drever, J. 1969. *A dictionary of psychology.* Revised by Harvey Wallerstein. Baltimore: Penguin Books.

Dunlap, K. 1917. The Johns Hopkins chronoscope. *J. Exper. Psychol.* 2:249-52.

Dunlap, K. 1918. Methods of using balanced-magnet chronoscopes. *Psychobiology* 1:445-57.

English, H. B. 1942. How psychology can facilitate military training–a concrete example. *J. Appl. Psychol.* 26:3-7.

English, H. B. and English, A. C. 1958. *A comprehensive dictionary of psychological and psycho-analytical terms, a guide to usage.* New York: McKay.

Feigenbaum, E. A. and Feldman, J., eds. 1963. *Computers and thought.* New York: McGraw-Hill Book Co.

Fleming, A. 1841. On the use of the globes in teaching geography and astronomy. *American Institute of Instruction.* (Boston), pp. 163-78.

Fleming, D. 1952. *Science and technology in Providence 1760-1914: an essay in the history of Brown University in the metropolitan community.* Providence: Brown University.

Foltz, C. I. 1961. *The world of teaching machines: programmed learning and self-instruction devices.* Washington, D. C.: Teaching Research & Technology Division, Electronic Teaching Laboratories.

Frost, S. E. 1937. *Education's own stations: the history of broadcast licenses issued to educational institutions.* Chicago: The University of Chicago Press.

Galanter, E. H., ed. 1959. *Automatic teaching: the state of the art.* New York: John Wiley & Sons, Inc.

Garvin, P. L., ed. 1970. *Cognition: a multiple view.* New York: Spartan Books.

Glaser, R. 1965. *Teaching machines and programmed learning, II.* Washington: Department of Audiovisual Instruction, National Education Association of the United States.

Goodrich, S. G. 1829; 1836. *Peter Parley's method of telling about geography to children.* With nine maps and seventy-five engravings, principally for the use of schools. New York: F. J. Huntington & Co.

Goodrich, S. G. 1856. *Recollections of a lifetime, or, Men and things I have seen: in a series of familiar letters to a friend, historical, biographical, anecdotical, and descriptive.* New York: Miller, Orton and Mulligan.

Gray, A. 1841. On the importance of the natural sciences in our system of popular education. *American Institute of Instruction* (Boston), pp. 91-142.

Guthrie, E. R. 1935. *Psychology of learning.* New York: Harper.

Hall, A. R.; Holmyard, E. J.; Singer, C.; and Williams, T. I., eds. 1958. *A history of technology, vol. 5, the late nineteenth century 1850-1900.* New York: Oxford University Press.

Harper, R. J. C.; Anderson, C. C.; Christensen, C. M.; Hunka, S. M., eds. 1964. *The cognitive processes.* Readings. Englewood Cliffs: Prentice-Hall, Inc.

Haskell, 1841. *On school apparatus, Conn. Common School Journal,* 99-100. Cited by Anderson 1962.

Hebb, D. O. 1949. *The organization of behavior: a neuropsychological study.* New York: John Wesley and Sons, Inc.

Hickey, A. E., ed. 1968. *Computer-assisted instruction: a survey of the literature.* Newburyport, Mass. : ENTELEK Inc.

Hilgard, E. R., and Marquis, D. G. 1940. *Conditioning and learning.* ed. R. M. Elliott. New York: Appleton-Century-Crofts, Inc.

Hindle, B. 1956. *The pursuit of science in revolutionary America 1735-1789.* Chapel Hill: The University of North Carolina Press.

Hindle, B. 1966. *Technology in early America: needs and opportunities for study.* With a directory of artifact collections, by Lucius F. Ellsworth. Chapel Hill: University of North Carolina Press.

Holtzman, W. H. 1970. *Computer-assisted instruction, testing, and guidance.* New York: Harper & Row.

Hume, D. 1749, 1777. Enquiry concerning human understanding. London.

International Brain Research Organization (IBRO). 1968. *Survey of research facilities and manpower in brain sciences in the United States.* Washington: National Academy of Sciences.

Jastrow, J. 1893. The Selection of Psychology; Growth and Development. In World's Columbian Exposition. 1893. *Official Catalogue.* Part XII, pp. 50-64. Chicago: W. B. Conkey Co.

Jensen, B. T. 1949. An independent-study laboratory using self-scoring tests. *J. Educ. Res.* 43: 134-137.

Johnson, C. 1904, 1963. *Old-time schools and school books.* With a new introduction by Carl Withers. New York: Dover Publications. Reprint.

Jones, R. S. 1954. Integration of instructional with self-scoring measuring. *Abstracts of Doctoral Dissertations,* no. 65. Columbus: The Ohio State University Press.

Langer, S. K. 1967. *Mind: an essay on human feeling.* vol. I. Baltimore: The Johns Hopkins Press.

Lavoisne, C. V. 1820. *A complete genealogical, historical, chronological and geographical atlas; being a general guide to history, both ancient and modern: . . . Enlarged by the addition of several new maps of American history and geography, which are brought down to the beginning of the year 1820.* Philadelphia: M. Carey and Son.

Lehmann-Haupt, H. 1939. *The book in America. A history of the making, the selling, and the collecting of books in the United States.* In collaboration with Ruth Shepard Granniss and Lawrence C. Wroth. New York: R. R. Bowker Co.

Lehmann-Haupt, H. 1951. *The book in America. A history of the making and selling of books in the United States.* 2nd ed. In collaboration with Lawrence C. Wroth and Rollo G. Silver. New York: R.R. Bowker Co.

Lekan, H. A., ed. 1969. *Index to computer-assisted instruction.* Milwaukee: The University of Wisconsin-Milwaukee: Instructional Media Laboratory.

Lekan, H. A. 1970. *Index to computer-assisted instruction.* 2nd ed. Boston: Sterling Institute.

Little, J. K. 1934. Results of use of machines for testing and for drill upon learning in educational psychology. *J. Exper. Educ.* 3: 45-49.

Lumsdaine, A. A., and Glaser, R., eds. 1960. *Teaching machines and programmed learning.* Washington: Department of Audiovisual Instruction, National Education Association of the United States.

Lurie, E. 1960. *Louis Agassiz: a life in science.* Chicago: The University of Chicago Press.

McCulloch, W. S. 1965. *Embodiments of mind.* Cambridge: The M. I. T. Press.

McCulloch, W. S. and Pitts, W. 1943. A logical calculus of the ideas immanent in neural nets. *Bull. Math. Biophysics* 5: 115-137.

Mannheim, K. 1936. *Ideology and utopia; an introduction to the sociology of knowledge.* With a preface by Louis Wirth. New York: Harcourt, Brace, and Company.

Meetham, A. R. and Hudson, R. A., eds., 1969. *Encyclopaedia of linguistics, information and control.* New York: Pergamon Press.

Mellan, I. 1936. Teaching and educational inventions. *J. Exp. Educ.* 4: 291-300.

Michaelis, A. R. 1958. The photographic arts: cinematography. In *A history of technology,* eds. A. R. Hall; E. J. Holmyard; C. Singer; and T. Williams, pp. 734-51. New York: Oxford University Press.

Miller, P. 1961. *The New England mind. The seventeenth century.* Boston: Beacon Press.

Miller, P. 1965. *The life of the mind in America; from the Revolution to the Civil War.* New York: Harcourt, Brace & World, Inc.

Minsky, M. 1967. *Computation: Finite and infinite machines.* Englewood Cliffs: Prentice-Hall.

Minsky, M. and Papert, S. 1969. *Perceptrons. An introduction to computational geometry.* Cambridge: The M. I. T. Press.

Monroe, W. S. 1907; 1969. *History of the Pestalozzian movement in the United States.* New York: Arno Press. Reprint.

Montessori, M. 1912. *The Montessori method; scientific pedagogy as applied to child education in "The children's houses" with additions and revisions by the author.* Translated from the Italian by A. E. George; with an introduction by H. W. Holmes. New York: Frederick A. Stokes Co.

Mosier, R. D. 1947. *Making the American mind: social and moral ideas in the McGuffey readers.* New York: King's Crown Press.

Müller, G. E. and Schumann, F. 1894. Experimentelle Beiträge zur Untersuchung des Gedächtnisses. *Z. Psychol.* 6: 81-190; 257-339.

[Münsterberg, H.] 1893. *Psychological laboratory of Harvard University.* Cambridge: [Harvard] University Press.

Neef, J. 1808, 1969. *Sketch of a plan and method of education, founded on an analysis of the human faculties, and natural reason, fitted for the offspring of a free people, and for all rational beings.* Reprint. New York: Arno Press.

Nye, R. B. 1960. *1776-1830. The cultural life of the new nation.* New York: Harper & Row, Harper Torchbooks, The University Library.

Oliver, J. W. 1956. *History of American technology.* New York: The Ronald Press Co.

[Pestalozzi.] 1801. *Leonard and Gertrude.* Philadelphia: J. Groff.

Peterson, J. C. 1930. A new device for teaching, testing, and research learning. *Transactions of the Kansas Academy of Science.* 33: 41-47.

Peterson, J. C. 1931. The value of guidance in reading for information. *Transactions of the Kansas Academy of Science.* 34: 291-96.

Piaget, J. 1952. [Autobiography] in *A history of psychology in autobiography.* Edited by Boring, E. G. Vol. 4, pp. 237-256.

Pierce, J. R. 1961. *Symbols, signals and noise: the nature and process of communication.* New York: Harper & Brothers.

Plimpton, G. A. 1916. *The hornbook and its use in America.* Proc. Amer. Antiq. Soc. n.s. 26: 264-272.

Popplestone, J. A. and McPherson, M. W. 1971. Prolegomenon to the study of apparatus in early psychological laboratories circa 1875-1915. *American Psychologist* 26: 656-57.

Porter, D. 1957. A critical review of a portion of the literature on teaching devices. *Harvard Educational Review.* 27: 126-47.

Pressey, S. L. 1926. A simple apparatus which gives tests and scores–and teaches. *School and Society* 23:373-76.

Pressey, S. L. 1927. A machine for automatic teaching of drill material. *School and Society* 25: 549-52.

Pressey, S. L. 1932. A third and fourth contribution toward the coming 'industrial revolution' in education. *School and Society* 36: 668-72.

Pressey, S. L. 1950. Development and appraisal of devices providing immediate automatic scoring of objective tests and concomitant self-instruction. *J. Psychol.* 29: 417-47.

Pursell, C. W., Jr. (Comp.) 1969. *Readings in technology and American life.* New York: Oxford University Press.

Ramsey, G. F. 1938. *Educational work in museums of the United States; development, methods and trends.* New York: The H. W. Wilson company.

Rath, G. J.; Anderson, N. S.; and Brainerd, R. C. 1959. The IBM research center teaching machine project. In *Automatic teaching: the state of the art.* ed. E. H. Galanter, chap. 11, pp. 117-30. New York: John Wiley & Sons.

Reitman, W. R. 1965. *Cognition and thought; an information-processing approach.* New York: Wiley.

Rich, A. L. 1946. *Lowell Mason, "the father of singing among the children."* Chapel Hill, The University of North Carolina press.

Russell, B. R. 1927. *Philosophy.* New York: W. W. Norton & Co. Inc.

Saettler, P. 1968. *A history of instructional technology.* New York: McGraw-Hill Book Co.

Sass, M. A. and Wilkinson, W. D. 1965. *Symposium on computer augmentation of human reason.* Washington, D. C.: Spartan Books Inc.

Severin, D. G. 1955. Appraisal of special tests and procedures used with self-scoring instructional testing devices. *Abstracts of doctoral dissertation,* no. 66. Columbus: The Ohio State University Press.

Shannon, C. E. and McCarthy, J. 1956. *Automata studies.* Princeton: Princeton University Press.

Shannon, C. E. 1949. *The mathematical theory of communication.* Urbana: University of Illinois Press.

Skinner, B. F. 1954. The science of learning and the art of teaching. *Harvard Educational Review* 24: 86-97.

Skinner, B. F. 1958. Teaching machines. *Science* 128: 969-77.

Stephens, A. L. 1953. Certain special factors involved in the law of effect. *Abstracts of doctoral dissertations.* No. 64. Columbus: The Ohio University Press.

Stevens, S. S. (ed.) 1951. *Handbook of experimental psychology.* New York: John Wiley & Sons, Inc.

Stoelting, C. H. 1936. *Apparatus, tests and supplies for psychology, psychometry, psychotechnology, psychiatry, neurology, anthropology, phonetics, physiology, and pharmacology.* Chicago: C. H. Stoelting Co.

Thomson, R. 1968. *The Pelican history of psychology.* Baltimore: Penguin Books.

Thorndike, E. L. 1898. *Animal intelligence; an experimental study of the associative processes in animals.* [Psychol. Monograph No. 8.] New York and London: The Macmillan Company.

Thorndike, E. L. 1903. *Educational psychology.* New York: Lemcke and Buechner.

Thorndike, E. L. 1911. *Animal intelligence, experimental studies.* New York: Macmillan.

Titchener, E. B. 1902. *Experimental psychology: a manual of laboratory practice, vol. 1, qualitative experiments: part 1, Student's manual.* New York: Macmillan.

Titchener, E. B. 1905. *Experimental psychology.* Quantitative. New York: Macmillan.

Tolman, E. C. 1932. *Purposive behavior in animals and men.* New York: Appleton-Century Crofts.

Tuer, A. W. 1897, 1968. *History of the hornbook.* Reprint of 1897 edition. New York: B. Blom.

United States Centennial Commission 1876. *International Exhibition.* 1876. Philadelphia: John R. Nagle & Co.

United States Centennial Commission 1880. *International Exhibition.* 1876. *Reports and awards,* vol. VIII. Groups XXVIII - XXXVI, and collective exhibits. Washington: GPO.

Watson, J. B. 1914. *Behavior, an introduction to comparative psychology.* New York: H. Holt and Co.

Watson, J. B. 1916. The place of the conditioned reflex in psychology. *Psychol. Rev.* 13: 89-117.

Watson, J. B. 1919. *Psychology from the standpoint of a behaviorist.* Philadelphia: J. B. Lippincott.

Watson, J. B. 1925. *Behaviorism.* New York: The People's Institute Publishing Co., Inc. W. W. Norhan & Company, Inc.

Webster, W. G. 1850. *A sequel to Webster's elementary spelling book; or, A speller defined.* 70th thousand. New York: George F. Cooledge & Brothers.

Wertheimer, M. 1912. Experimentelle Studien über das Sehen von Bewegugn. *Z. Psychol.* 61: 161-265.

Wesley, E. B. 1957. *NEA: The first Hundred Years; The building of the teaching profession.* New York: Harper & Brothers.

Wiebe, E. 1869. *The paradise of childhood: a manual for self-instruction in Friedrich Froebel's educational principles, and a practical guide to kinder-gartners.* Springfield, Mass.: Milton Bradley & Co.

Wiener, N. 1948. 1961. *Cybernetics: or, control and communication in the animal and the machine.* First edition New York: J. Wiley. 2nd ed. Cambridge: The M. I. T. Press.

Wiener, N. 1956. *The human use of human beings, cybernetics and society.* Boston: Houghton Mifflin.

Windelband, W. 1958. *A history of Philosophy, vol. II, Renaissance, Enlightenment, and Modern.* New York: Harper & Brothers.

Woelfle, D. 1951. *Handbook of experimental psychology.* S. S. Stevens, ed. Chapter 34, pp. 1267-86.

Woodworth, R. S. 1938. *Experimental psychology.* New York: Henry Holt and Co.

Woodworth, R. S. and Schlosberg, H. 1954. *Experimental psychology.* New York: Henry Holt and Co.

Zimmerman, E. 1912. *Psychologische und Physiologische, Apparate,* List 25. Leipzig/Berlin: E. Zimmerman [?].